The Surgery of Pulmonary Tuberculosis

By James H Forsee, A B B S M D, F A C S, F A C P

Colonel M C U S Army Chief Surgical Services Fitzsimons Army Hospital Denver Colorado

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Dedicated

to

My Wife and Son

for

Their Love and Patience

and to the

Soldiers, Sailors, Airmen

and

Their Dependents Who Have Been My Patients

Foreword

This book is greatly needed and Colonel Forsee is to be congratulated on having accomplished a really monumental task so expeditiously He has produced a monograph which will bring the reader up to date with the latest thought on the application of surgery to the treatment of pulmonary tuberculosis In the short period since the end of World War II there has been practically a revolution in our thinking about the performance of direct surgical procedures for the purpose of removing the diseased portion of the lung Resectional or extirpative surgery is apparently going to supplant to a large extent those surgical measures aimed at producing collapse of the lung

The history of the surgery of pulmonary tuberculosis affords a good example of the swinging of the pendulum which is commonly seen in medicine Shortly before the beginning of the present century several attempts were made to remove the diseased parts of the lungs in cases of pulmonary tuberculosis and in fact two cases were successful according to Stephen Paget who in 1896 wrote the first book on chest surgery * One operation for the removal of the tuberculous apex of the right lung was performed by Tuffier the great French surgeon in 1891 The patient nineteen years old at the time of the operation was said to be well four years later The other case was also the removal of the tuberculous apex of the right lung The operation was performed in 1893 by Lowson of England and the patient lived for nine months when she died supposedly of a gastric ulcer associated with hemorrhages

In other cases however the operations were not successful and because of the prohibitive mortality associated with resectional surgery the procedures were abandoned The safer collapse operations became popular in the 1920's Now especially since 1945 there has been a revival of the direct surgical attack for the removal of the diseased lung tissue Apparently this time these procedures are here to stay until such time as there may be an effective medical or non-surgical treatment of tuberculosis Colonel Forsee has presented in an interesting manner the development of the modern operations and he has given good descriptions of the technical procedures as well as the indications for their use. The large number of tuberculous patients under the care of himself and his associates at the well known Fitzsimons Army Hospital has constituted sufficient clinical material to have statistical significance The record of accomplishment is splendid

It is pleasing to read the plea for the care of tuberculous patients in general hospitals where there will be the advantages afforded by a medical staff qualified in all the specialties of modern medical science and practice Certainly patients who happen to have tuberculosis are entitled to have the skills which modern specialists can bring to bear on their cases instead of being cast off in isolated sanitariums where too often they are deprived of those skills.

Evarts A Graham

* The Surgery of the Chest John Wright & Co Bristol England

Preface

The last seven of twenty-five years' experience with the surgery of pulmonary tuberculosis have witnessed the striking advances portrayed in this book The advent of streptomycin and the subsequent development of certain other chemotherapeutic agents have completely altered the treatment of tuberculosis Through the effectiveness of these drugs in the resolution and localization of the pulmonary manifestations of tuberculosis, surgical therapy has increased in its incidence of application fivefold, with no end in sight as to its future utilization Rest, chemotherapy, and surgery have inaugurated a new era which permits a relatively exact forecast to the patient of the time required for the total therapy of his disease A period of hospital care longer than one year after surgery is seldom required, and the period before surgery seldom need be that long There are only a few patients who are not able to return to normal activities within two years after surgery.

The effective surgical removal of tuberculous lung tissue has been a goal long sought by all who are closely concerned with the therapy of this disease This goal has been reached Ninety-one per cent of patients treated during the past seven years at Fitzsimons Army Hospital by the removal of a part or all of a tuberculous lung are well, working, able to work, or their prognosis for complete rehabilitation is excellent The indications, distribution of extirpative surgical methods employed, operative techniques, chemotherapeutic program, length of hospitalization, and physical medicine adjuncts are presented in detail The one-man, tuberculosis expert is becoming extinct The tuberculosis therapy team composed of experts in phthisiology, surgery, pathology, bacteriology, roentgenology, physical medicine, nursing, hospital administration, public health, social work, and appropriate research, comprise the championship team which is achieving an unprecedented record of therapeutic advances applicable to the tuberculous patient These facilities have been available and utilized Much of the success of the surgical therapy herein recorded is directly attributable to this team of experts in other fields

I am indebted to many for their participation in the activities which comprise the source material of this book To the staff of this hospital, present and past, I owe much for what they have taught me, in addition to their efforts extended in patient care The staffs of Veterans Administration Hospitals and many physicians engaged in private practice have generously furnished follow-up data Such data are available in more than 99 per cent of the patients, approximately 1000, who have undergone surgery for pulmonary tuberculosis at Fitzsimons Army Hospital since 1947 Brigadier General Paul I Robinson, Commanding General, Fitzsimons Army Hospital, has steadfastly encouraged this effort and has made available facilities permitting its completion To the late Colonel Robert

W DuPriest and to Colonel John M Salyer my surgical associates during most of this period I am indebted for their assistance in sharing a heavy load of the operative surgery Colonel Carl W Tempel, Chief of the Medical Service ably supervised the medical phases of the care of the tuberculous patients The residents in general and thoracic surgery have furnished an inspiring stimulus to me to write this book and I have profited greatly from being associated with them Mrs Jean V Elwell has been largely responsible for the collecting and the excellency of the follow-up data. Miss Wilma K. Gillespie my secretary has diligently supervised and typed most of the manuscript I am most grateful to both Captain William P Creger has read the manuscript and offered many helpful suggestions in its preparation

JAMES H FORSEE

Denver Colorado

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The Patient and His Disease

The Challenge of Recovery Surgical principles in the treatment of pulmonary tuberculosis embrace full consideration of the patient the disease process the available facilities and chemotherapeutic agents as well as the selection timing and application of surgical procedures The patient and his disease constitute a paramount consideration The mental and environmental disturbances the patient may suffer during the course of active pulmonary tuberculosis are profound Failure or delay in meeting these aspects of the disease is more common than rendering improper medical and surgical treatment These problems are often made even more difficult by prolonged periods of waiting at home before suitable hospital facilities for patient care are made available. Pressing as these sociological problems are in our own country they are so desperate in many other parts of the world that therapeutic endeavors against pulmonary tuberculosis almost assume a secondary role. The avenues which have not even been explored by surgery in these localities are challenges far beyond medical responsibility and require valiant accomplishments by combined human efforts If every person afflicted with active pulmonary tuberculosis could be hospitalized and afforded complete therapeutic facilities as soon as the disease is detectable retained under proper medical care until the disease is inactive and complete rehabilitation measures assured it is reasonable to predict that death or prolonged disease due to uncomplicated pulmonary tuberculosis might well become a rarity The challenge of recovery diminishes as therapy improves Our experience is demonstrating that if the above conditions are adhered to more than 95 per cent of patients receiving surgical therapy for uncomplicated pulmonary tuberculosis are being completely rehabilitated and incur no undue risk of disease reactivation

Establishment of Diagnosis. The establishment of the diagnosis in active pulmonary tuberculosis is generally simple and is based on the identification of the tubercle bacillus in the sputum gastric content or excised

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Establishment of Diagnosis. The establishment of the diagnosis in active pulmonary tuberculosis is generally simple and is based on the identification of the tubercle bacillus in the sputum gastric content or excised

pulmonary tissue However, to satisfy this elementary requirement, the search may be devious, involving surgical exploration of the lung, excision of suspected tissue, histopathologic examination of the tissue by a pathologist experienced in diseases of the chest, and the securing of confirmatory evidence by identifying the tubercle bacillus from such ancillary material Several aids in establishing the diagnosis are available The clinical history and course of the ailment give the physician valuable hints as to the possible presence of tuberculosis Hemoptysis always directs attention toward such an etiological consideration Even an acute onset of chills, fever, and prostration is not unusual Cough, loss of weight, and undue fatigue are classical signals The chest roentgenogram is often so revealing as to make it the most valuable of all aids and is usually positive before symptoms are manifested Apical areas of linear and nodular densities, translucencies in the lung field, or areas of consolidation, all suggest tuberculosis Partial or complete stenosis of the bronchi is most frequently of tuberculous origin The bronchoscopic aspiration of secretions may permit the identification of tubercle bacilli despite repeated failures in the examination of the sputum

With the increased use of certain chemotherapeutic agents a new problem has arisen relative to the isolation of the tubercle bacillus from patients who are probably afflicted with this disease Following the use of these drugs, for several weeks or months, it is commonly noted that acid-fast bacilli are not found in the sputum If the drug is then discontinued, tubercle bacilli are again identifiable in the sputum Following the protracted use of chemotherapy and if the sputum remains positive or specific microorganisms are identifiable in the surgically removed tissue, it is commonly noted that the tubercle bacillus cannot be grown on laboratory culture media, nor are they clearly virulent in experimental animals This problem is of considerable significance in the surgical therapy of pulmonary tuberculosis The excision of small residual foci in patients who have received chemotherapy such as streptomycin and para-aminosalicylic acid for a protracted period, *i e*, six to eighteen months, is controversial These patients often have (1) negative sputum or gastric cultures for several months preoperatively, (2) maximum resolution of lesions as evidenced by serial roentgenograms, and (3) no evidence of previously observed cavities on the roentgenogram These lesions which are surgically removed have demonstrable acid-fast bacilli on smear in approximately 65 to 80 per cent of the excisions However, the microorganisms cannot be grown on laboratory culture media, and inoculations of the material into guinea pigs does not produce typical disease except in a small per cent of animals

In a study reported from the Veterans Administration Hospital, Sunmount, New York, 129 residual foci of closed lesions removed surgically were examined by culture or guinea pig inoculation Only 2 3 per cent were positive for viable bacilli by this method, while 67 per cent of 99 lesions were positive on smear These patients received streptomycin, 1 gram daily, and para-aminosalicylic acid, 12 grams daily, for four months or longer In 32 patients similarly treated for more than eight months, viable bacilli were not demonstrated in any of the resected lesions Sixty-one per cent of the resected lesions with open cavitation contained viable

tubercle bacilli The number of patients in this group was only 13[6] Our experience has been similar Experience is insufficient and the period of follow-up study too short to permit final evaluation of this problem One should be mindful of the observed fact that in those individuals who have demonstrable tuberculous residual foci it is certain that the foci originated from the action of viable tubercle bacilli The establishment of a diagnosis of active pulmonary tuberculosis rests on the demonstration of the tubercle bacillus in the sputum gastric content or surgically excised lung tissue and the determination of the viability of the microorganism cannot at present be the criterion for diagnosis.

Planning Treatment. An individual with active pulmonary tuberculosis should be counseled at an early date as to the need for hospital care the facilities available and the length of time such care may be needed This timely and considered appraisal must emphasize that the excellent results being obtained through the use of chemotherapeutic agents, does not at this time warrant lessening the emphasis on properly supervised bed rest in a hospital We may be approaching an era wherein even more effective medication will permit quicker regression of established lesions and prevent dissemination by killing the tubercle bacillus It seems feasible to await the arrival of that era before patients are generally advised to discontinue hospitalization prior to the time that their disease is inactive In many instances surgery will not be contemplated However the patient should be carefully briefed as to its role in total therapy so that both unwarranted expectations and unnecessary fears on the part of the patient may be prevented

General Hospital. The general hospital offers many advantages for the care of tuberculous patients No longer need this be a dismal disease resulting in the indefinite occupancy of a bed in a busy general hospital that can ill afford such a protracted patient stay The advantages afforded by a medical staff qualified in all the specialties of modern medical science and practice allow readily available complete patient care beyond that required by a single disease usually manifested in the lungs The complete laboratory and roentgenographic facilities of a well run general hospital readily fit into this over-all category of patient care Often the wider interests and phases of research and development result in benefit to the tuberculous patient These desirable features of the general hospital do not permit laxity in isolation methods in the management of such a communicable disease as pulmonary tuberculosis The planning and construction of general hospitals might well give renewed interest and consideration to the inclusion of an appreciable number of beds for the care of tuberculous patients.

Tuberculosis Sanatorium. The tuberculosis sanatorium may provide excellent care for tuberculous patients It will however fall far short of its responsibilities if the auxiliary facilities of a well organized general hospital are not provided Surgery is now so well established in the treatment of pulmonary tuberculosis that a sanatorium dedicated to the care of tuberculous patients needs experts in all phases of the surgical treatment of this disease including pathologists anesthetists endoscopists roentgenologists, and physiatrists The practice of sending the patient to a

pulmonary tissue. However, to satisfy this elementary requirement, the search may be devious, involving surgical exploration of the lung, excision of suspected tissue, histopathologic examination of the tissue by a pathologist experienced in diseases of the chest, and the securing of confirmatory evidence by identifying the tubercle bacillus from such ancillary material. Several aids in establishing the diagnosis are available. The clinical history and course of the ailment give the physician valuable hints as to the possible presence of tuberculosis. Hemoptysis always directs attention toward such an etiological consideration. Even an acute onset of chills, fever, and prostration is not unusual. Cough, loss of weight, and undue fatigue are classical signals. The chest roentgenogram is often so revealing as to make it the most valuable of all aids and is usually positive before symptoms are manifested. Apical areas of linear and nodular densities, translucencies in the lung field, or areas of consolidation, all suggest tuberculosis. Partial or complete stenosis of the bronchi is most frequently of tuberculous origin. The bronchoscopic aspiration of secretions may permit the identification of tubercle bacilli despite repeated failures in the examination of the sputum.

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In a study reported from the Veterans Administration Hospital, Sunmount, New York, 129 residual foci of closed lesions removed surgically were examined by culture or guinea pig inoculation. Only 2.3 per cent were positive for viable bacilli by this method, while 67 per cent of 99 lesions were positive on smear. These patients received streptomycin, 1 gram daily, and para-aminosalicylic acid, 12 grams daily, for four months or longer. In 32 patients similarly treated for more than eight months, viable bacilli were not demonstrated in any of the resected lesions. Sixty-one per cent of the resected lesions with open cavitation contained viable

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distant or nearby general hospital to have surgical operations performed, and returning the patient to the sanatorium after a few days, has developed through necessity In the future, the planning, staffing, and construction of tuberculosis sanatoria should be predicated upon a self-sufficient installation for the complete care of all problems likely to arise in a large group of tuberculous patients This means essentially all the professional facilities of a general hospital Therein will probably be found the most effective and economical hospitalization of the tuberculous patient

Tuberculosis Therapy Team. Planning treatment for the individual with active pulmonary tuberculosis is a team effort, and continuity with adaptation to changing concepts must characterize the principles of such responsibility The patient, the medical and nursing staffs, social workers, hospital administrators, and all who are concerned with patient care must enthusiastically participate in the planning Few, if any, members of the medical staff, expert though they may be, who are alert to present trends and accomplishments and who are imaginative as to future developments, will find consolation in the fact that disease progression has occurred when counsel with colleagues has not been sought Often the advice of such associates will be beneficial, and the close coordination of their efforts is essential for proper patient care Fortunately, the one-man tuberculosis specialist is becoming extinct Today, the surgeon, phthisiologist, endoscopist, radiologist, pathologist, and others devoting a part or all of their time to tuberculosis problems, comprise a championship tuberculosis therapy team

Orientation as to Surgical Therapy. Early in the discussion of treatment the patient should be apprised of the place of surgery in the over-all therapy plan As the course of the disease becomes better defined and surgery is considered feasible, the patient should be so informed A conference with the patient, surgeon, phthisiologist and other members of the therapy team is in order

In general, the plan of treatment which our experience has shown to be especially beneficial is as follows Within a few days after admission of an individual who has tuberculosis, he is counseled by the doctor, nurse and social worker regarding the basic facts of the contagious nature of the disease He is furnished with certain brief but authoritative literature written especially for the layman concerning pulmonary tuberculosis. He is encouraged to know about his disease and to ask questions In about one week a friendly conference between the patient and the doctor is arranged; this usually requires about one hour It is informal and the patient is encouraged to discuss any problems such as family matters, finances, length of hospitalization, etc He is asked questions to ascertain if he has a satisfactory understanding of his disease The rules of the hospital are reviewed and explained Case problems similar to his own, without mentioning patients' names, are briefly reviewed in order that the patient may be relieved of a feeling that this happens "only to me" The recovery of such patients and their return to an active life in various fields of endeavor is stressed

If surgery is considered indicated, all phases of the patient's case history are reviewed by the Chest Surgery Review Board. An informal dis-

cussion follows and recommendations agreed upon by the thoracic surgeon and phthisiologist are presented to the patient The patient who is thus properly informed seldom declines the recommendation Surgical therapy is carried out within a few days of decision as delay in its accomplishment is often frustrating to the patient anxiously anticipating its benefits

The patient is informed of the favorable morbidity and mortality statistics of surgical measures directed toward arresting and curing pulmonary tuberculosis For example a stage of a thoracoplasty operation in a patient who is not ill with empyema has a mortality rate of less than one-half of 1 per cent The figure for extirpative surgical procedures except pneumonectomy approximates 1 per cent Such factual data encourage the patient's confidence in surgical therapy His hopes for complete rehabilitation will be heightened when he is informed that present accomplishments demonstrate that probably 95 per cent of patients receiving properly timed and executed surgery in the treatment of uncomplicated pulmonary tuberculosis along with the best new chemotherapeutic agents will be able to return to gainful occupations without undue risk of reactivation of tuberculosis. This estimate is predicated on the observation that such a program will result in almost eliminating the need for pneumonectomy that the number of lobectomies performed will be decreased and that surgical consideration will be focused chiefly on the removal of foci present after months of bed rest and drug therapy Even now our experience demonstrates that 90 per cent of patients treated by upper lobectomy and five-rib thoracoplasty are sputum negative and are working or able to work within two years after such operations The presentation of such facts through the organization of clubs or societies of ex patients who counsel those presently under treatment, is most effective

This appealing picture does not imply that pulmonary tuberculosis is a less serious disorder if proper treatment is not accomplished Because it is now possible to indicate with considerable accuracy the time required to obtain disease inactivation the practice of patients leaving the hospital against medical advice after short and inadequate periods of treatment is steadily diminishing During 1952 less than 2 per cent of members of the Armed Forces who were undergoing treatment for active pulmonary tuberculosis at Fitzsimons Army Hospital left before the time advised The complete continuous period of therapeutic direction from initial diagnosis to full rehabilitation is ideal and is being approached more closely all the time

Condition of the Patient. Surgery in the treatment of pulmonary tuberculosis is no longer a problem concerned largely with the poor risk patient If the disease is detected early and this is largely feasible by annual roentgenographic examination the patients will in a few years almost always be young and in good general health The debilitating features of the older age group *i.e.* heart disease and arteriosclerosis would then seldom be encountered The dissemination of tuberculosis to other organs such as the liver gastrointestinal tract and larynx as evidenced at necropsy prior to the chemotherapy approximates 50 per cent [1] Evidence of such manifestations singly or in combination was present in only 5 per cent of patients treated surgically for pulmonary tuberculosis during

the period January 1, 1947 to December 31, 1952. This means that the application of surgery has been so timed during the course of the disease as to minimize mortality and morbidity because of improved operative risk in the patients selected

Age, Race, Sex and Extent of Disease. The case material represented in our study is varied and usually the patients are in better general condition than is frequently encountered in a large group of tuberculosis patients The patients are predominantly young male soldiers, although about 25 per cent are veterans of World War II The average age of patients undergoing thoracoplasty or extirpative surgery was 30 5 years Seventy-nine per cent were males The race incidence was as follows Caucasian, 85 per cent, Negro, 13 per cent, and Asian, 2 per cent Results have been equally good whether Caucasian or Negro The extent of disease was variable, the majority having extensive disease However, the benefit to be derived from receiving the patient early in the course of his disease, inaugurating the chemotherapy regimen, and continuing therapy until an inactive state is reached, is immeasurable Fortunately, this situation pertains in approximately two-thirds of our patients

Duration of Disease The increasingly good results of surgical therapy obtained among those patients who are operated upon relatively early during the course of their disease, *i e*, within one year, are in striking contrast to the prolonged period, approximately four years, of disease duration before surgery was accomplished prior to the chemotherapy era

Case Selection. Thorough consideration of the selection of patients for surgical procedures is discussed under the respective procedure Certain general considerations may now be presented The presence of sustained fever, 100° F or more, except in association with empyema, generally warrants deferring operation The presence of active endobronchial tuberculous disease is generally a cause for postponement of surgery until the lesion is healed Erman reported the early experience in the use of streptomycin in endobronchial tuberculosis at Fitzsimons Army Hospital in 1950 [2] The study concerned a group of 49 patients with active endobronchial tuberculosis treated early with streptomycin intramuscularly It was not combined with any other drug An average of three bronchoscopic examinations were performed on each patient Complete healing without residual fibrosis occurred in 100 per cent of the 23 patients with hyperplastic endobronchial tuberculosis A similar finding was noted in the 15 patients with submucosal endobronchial disease Three patients in the group of 11 having ulcerative endobronchial tuberculosis healed with some degree of residual stenosis Similar good results have continued when streptomycin was combined with other drugs

The patient who has previously been unable to adjust to the requirements of bed rest and sanatorium treatment, should be accepted for surgery only if he now demonstrates a sincere effort toward making such an adjustment. The post-surgical observation period should be supervised by those who recommended and performed the surgery The practice of the patient being sent to a distant hospital for the performance of surgery, then being returned to a sanatorium for further care, without the surgeon actively participating in that care, leaves much to be desired The surgeon should

be equally as concerned with the post-surgical management as with the original selection of patients.

Surgery resorted to as a last-hope chance for recovery is entirely outmoded. Unfortunately, such patients are occasionally seen and even though the risk entailed by operation is great and the benefits doubtful it has been our practice to offer the patient the chance of benefit. The patient population of a hospital caring for a large number of tuberculous patients expects surgical therapy to be accomplished with a low morbidity and mortality. The reverberations of ill fated surgical efforts are potent influences in deterring the satisfactory risk patient from accepting proper recommendations for surgery. The refusals which result may outweigh the sincere, yet fruitless, effort made in a foredoomed undertaking.

Status of Chemotherapy. Since January 1, 1947 the so-called specific drug therapy for pulmonary tuberculosis has been extensively employed and carefully evaluated at Fitzsimons Army Hospital. The exact mode of action of these agents in pulmonary tuberculosis is not known and the excellent studies indicate that much additional research is required. In 1948, Mahon and his associates wrote "Streptomycin caused a hastening of the reparative process not because of any stimulating effect upon the tissues, but because of a suppressive birth control effect on the bacillus and that it could not produce healing in the absence of natural tissue resistance."[3] Chemical and bacteriological studies of closed lesions revealed that streptomycin was rarely found in the center of the lesion where acid-fast bacilli could not be cultured. These observations were confirmed by Medlar, and whether or not bacilli seen on smear but not culturally viable are alive or dead has not been determined.[4] Growth is readily obtained on cultures from open lesions indicating the effect of present chemotherapeutic agents, especially streptomycin, is not necessarily the cause of death of the tubercle bacilli. These studies have had a profound effect on the surgery of tuberculosis. The highly favorable results from extirpative surgical methods are due to the correlation of the chemotherapeutic and pathological aspects so that maximum regression of the disease takes place before excisional procedures are undertaken. Actually more and more patients with less and less pulmonary tuberculosis are being treated by extirpative procedures with increasingly good results. Data on 431 patients discharged from Fitzsimons Army Hospital in 1952 in whom the disease had reached an inactive state revealed that 23 per cent were treated by major surgical efforts. Ninety nine per cent of these latter patients received chemotherapeutic agents during the course of their treatment. Details regarding dosage, duration and agents employed are presented in relation to various surgical procedures in other chapters. In general the practice has been to administer these agents before, during and after surgery. The experience at Fitzsimons has been similar to that of others in regard to the combinations of agents and the regimens have been generally standardized. Tempel has summarized the experience at Fitzsimons of the pilot studies of drug regimens for pulmonary tuberculosis in 1288 patients treated during 1946–1952. Pertinent data from his summary are shown in Table 1.[5]

The fundamentals emphasized by Tempel to be considered in the employment of chemotherapy in the treatment of pulmonary tuberculosis include (1) The duration of the disease, (2) the reversibility of the lesions, (3) the destruction of lung tissue, (4) the extent and distribution of the lesions, (5) the nature of any associated lesions of the bronchi and pleurae, and (6) tuberculous disease in other organs The best response to drug therapy is in patients with exudative lesions New lesions of the caseous-penumonic variety respond well, cavitary disease less well, and the fibrous elements appear to undergo little, if any, alteration In many instances, there is a mixture of the new (exudative) and the old (fibrous) lesions, and favorable response to the chemotherapeutic agents by the former lesions is a large factor in permitting earlier surgical intervention with a high degree of safety and unprecedented results

Table I. Drug Regimens for Pulmonary Tuberculosis

Drug	*Years Employed*	*Bacterial Resistance (Per cent)*	*Result*
Streptomycin			
2 gm daily—120 days	1946	65–80	Toxicity great
1 gm daily—120 days	1947		Discontinued
1 gm daily—28–42 days	1948	15	No definitive value
Intermittent Dosage			
Streptomycin 1–2 gm every 3d day for 120 days	1947 1948	20–35	Improved over above
Combined Intermittent Regimen			
Streptomycin 1–2 gm every 3d day Para-aminosalicylic acid 12 gm daily	1949–52	0	Excellent
Streptomycin as above and Terramycin 2 gm daily	1952	0	Excellent
Streptomycin as above and Isoniazid 300 mg daily has replaced P A S	1952 & 1953	0	Excellent
Streptomycin, Isoniazid, and P A S are occasionally combined			

twelve months The benefits of surgery are being extended to many more patients. This increase has been from approximately 5 per cent prior to the chemotherapy era to 25 per cent and the latter figure may continue to rapidly rise The morbidity and mortality have been greatly reduced and the latter compares most favorably with commonly performed abdominal operations for nonmalignant diseases. The members of the Armed Forces who develop pulmonary tuberculosis receive an excellent therapy program This program combines early disease detection inauguration and the continuance of chemotherapy under the supervision of a group of physicians experienced in this and appropriate research methods surgical therapy relatively early in the course of their disease and complete rehabilitation Thus they are being afforded a richly rewarding opportunity for recovery with unprecedented favorable results The principles of this program are feasible on a wider basis

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Chapter

2

Pulmonary Tuberculosis as a Surgical Disease

General Considerations. Pulmonary tuberculosis is amenable to surgical treatment The basic principles concerned are (1) to provide rest for the diseased lung, (2) to remove diseased lung tissue, and (3) to provide drainage of infected pleural fluid and obliteration of the pleural space

The surgical measures which bring about rest for the lung are those commonly grouped as collapse therapy They are directed toward decreasing the size of the lung, usually by the extrapleural removal of ribs, the subcostal extraperiosteal placement of certain substances, or the elevation of the hemidiaphragm by interrupting the phrenic nerve The severing of intrapleural adhesions, in certain instances, where artificial pneumothorax has been induced, tends to increase the collapse of the lung and improve the pneumothorax Prior to the chemotherapy era these surgical measures constituted the principal features of surgical therapy

The appealing thought of removing pulmonary tissue containing tuberculous infection has long been the objective of surgical therapy This is, in a large measure, now being accomplished It is essential to emphasize that in many instances the total area of pulmonary or lymph node involvement is not removed, but the major portion is extirpated Dependence on healing of the remaining disease is placed in chemotherapy, partial collapse of the chest wall, and systemic rest

Drainage of tuberculous cavitary lesions by exposing the cavity to the atmosphere is advised by some authorities as a means of decreasing its size and ultimate obliteration I believe extirpation of such lesions is preferable to cavernostomy In the presence of infected pleural fluid, due to the tubercle bacillus alone, repeated thoracenteses and the local as well as systemic use of chemotherapy may result in resolution of the infection More often, and in the presence of a mixed infection or bronchopleural fistula, external drainage by catheter or rib resection is necessary The ultimate obliteration of the pleural space by either the reexpansion of the collapsed lung or by decreasing the size of the hemithorax is required

The features of pulmonary tuberculosis lending themselves to available surgical therapy are inciting increased interest as the beneficial effects of chemotherapy and improved surgical methods are receiving greater appreciation

The following section on the pathology of pulmonary tuberculosis in relation to surgical therapy has been prepared by Major Thomas F

Puckett Medical Corps U S Army Pathologist Fitzsimons Army Hospital

Pathology of Pulmonary Tuberculosis in Relation to Surgical Therapy

Pathogenesis When living or dead virulent or avirulent or even some types of non pathogenic acid fast bacilli are introduced into the tissues of an animal organism there is formed a typical and fundamentally identical lesion known as the tubercle.

The initial response of the tissue is of a nonspecific nature chiefly hyperemia, edema and leukocytic infiltration occurring in both allergic and nonallergic tissues. With minute doses tubercle formation may be incited in the absence of preliminary acute inflammation whereas with larger doses the preliminary inflammation response is proportionately greater in the allergic than in the nonallergic tissue[14] During the initial stage bacilli are ingested by polymorphonuclear leukocytes which are damaged or killed by the bacilli or their constituent products The tissue response then assumes the second stage which is more prolonged is designated as the proliferative stage and is characterized by the agglomeration of large mononuclear phagocytes probably derived from the blood monocytes and mobilized tissue cells These cells ingest nuclear debris damaged leukocytes and tubercle bacilli In doing so they enlarge their cytoplasm becomes pale and sometimes they contain a granular or foamy area probably due to the large lipid content of the bacilli Because of their resemblance to closely packed epithelial cells the term epithelioid cell has common usage The presence of phospholipids and perhaps some of the waxes from the bacilli causes fusion of the epithelioid cells and the formation of the familiar multinucleated giant cell of the Langhans type In the early phases of the tubercle formation the giant cell with peripherally arranged nuclei may be in the central portion and later be destroyed by caseation With the addition of peripheral epithelioid cells and enlargement of the lesion giant cells are usually found eccentrically or peripherally Surrounding the entire mass there is usually a poorly defined zone of lymphocytes

Caseation is the term applied to necrosis in which there is partial autolysis and the structure and outlines of the cells are lost and their remnants become fused with the intercellular material to form an amorphous crumbly granular mass[14] Caseous necrosis differs from ordinary coagulative necrosis by having a high lipid content and by the tendency for the necrotic material to persist for longer periods probably due to the inhibition of proteinase activity by the phosphatide of the tubercle bacilli[21] Small areas of necrosis may appear in experimental tuberculosis in two or three days and complete caseation begins to appear after large doses of virulent bacilli in relatively resistant animals in about two weeks[12]

It is the tubercle then with or without its central area of caseation its peripheral epithelioid cells and Langhans giant cells and its surrounding zone of lymphocytes and nonspecific inflammatory reaction that forms the building blocks from which all except one of the gross and microscopic forms of tuberculosis and their sequelae fibrosis are made In caseous pneumonia necrosis and exudation occur more rapidly than the proliferative phase and there is not sufficient time for the formation of tubercles

Caseation will progress as long as there is multiplication of organisms within the tubercle and the tubercle will continue to enlarge, but it should be stressed that the larger caseous foci are formed by the fusion and conglomeration of smaller foci rather than by simple enlargement of a single tubercle It is the tubercle and the structures it builds that is highly characteristic of tuberculosis and upon which we have relied for histologic diagnosis (Fig 1) It must be stressed that it is not specific and that similar building blocks and structures may be or are characteristic of other diseases such as coccidioidomycosis, histoplasmosis, blastomycosis, lues, leprosy, brucella infections, tularemia, schistosoma infestations, and some diseases of unknown etiology such as sarcoid and regional ileitis (Fig 2) It has become, therefore, the policy of our laboratory that tuberculosis is not diagnosed without identifying the organism either by smear or culture,

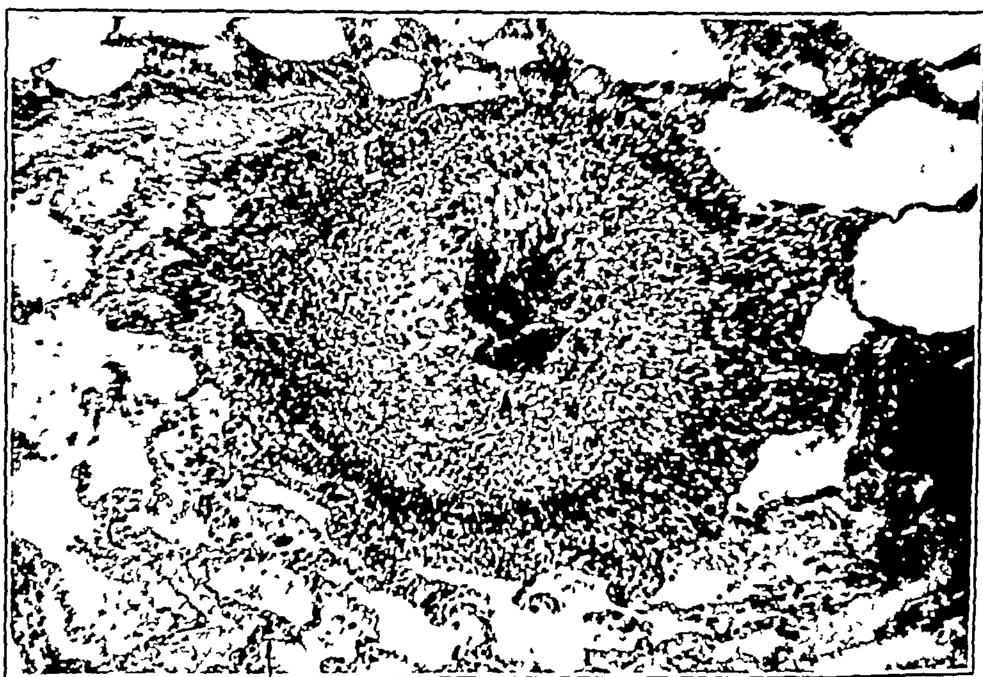


Fig 1 —Tubercle in lung Proved tuberculosis

from the resected specimen or in tissue sections from the specimen except in those uncommon instances where all of these studies are negative and there is a history of numerous positive cultures from sputum or gastric washings preoperatively In the latter instances the diagnosis of tuberculosis is made with some trepidation since our experience is similar to that of others, that concomitant fungous infections, while uncommon, are certainly not rarities

Granulomatous lesions in resected tissue from patients who have not had positive cultures for acid-fast bacilli and in which acid-fast bacilli cannot be identified by smears from the material, tissue stains or cultures of emulsions of the material present much more of a problem Careful study by tissue stains and cultural methods has shown that a considerable

number of these lesions are due to Coccidioides immitis Recently it has been shown that an additional number are due to Histoplasma capsulatum [11] There remains however a small number of cases wherein all methods of examination are carefully used but still no etiological agent can be identified At the present time lesions in the latter group are diagnosed as granulomatous reaction etiology undetermined

In the past lesions from the latter group were sometimes diagnosed as tuberculosis or probably tuberculosis It is in this group that we are called upon to use all of the data at our command in order to arrive at a reasonably accurate clinical diagnosis A knowledge of the natural history of granulomatous diseases and serial roentgenographs will sometimes aid in the clinical diagnosis When serial roentgenographs are not available



Fig 2 —Tubercle in lymphatic vessel due to histoplasmosis

as they frequently are not questioning regarding the residential history utilization of available materials for testing sensitivity and complement fixation and precipitin reactions may point toward or away from fungous infection Close questioning regarding contacts may also give useful information It is our current belief that the presence of a tuberculous lesion large enough to be demonstrable by a roentgenogram accompanied by a negative cutaneous reaction to tuberculin is a very rare circumstance indeed This of course does not include the far advanced cases exhibiting anergy and it should be added that the clinician should be absolutely certain in his own mind that the cutaneous reaction is negative In other words one negative skin test does not mean the absence of tuberculosis

There is then in this series a number of cases in which the diagnosis of tuberculosis was made by using a combination of clinical and pathological findings without demonstrating the etiological agent We think

we were right in so doing Perhaps some of these lesions were due to other organisms and the patients were subjected to unnecessary postoperative hospitalization It is our belief that by the use of the newer staining techniques and the careful study of resected lesions a diagnosis of tuberculosis based on clinical evidence alone will be made less frequently in the future It is hoped that further investigative study will continue to supply new tools for examination enabling us at some time in the future to make a positive etiological diagnosis in every case Over the period 1947–1952, 443 surgical specimens of pulmonary tissue have been thoroughly examined by all available methods A positive bacteriological diagnosis was not tenable in 46 instances This problem is a difficult one and in each instance a careful appraisal in consultation with the clinicians has been made The evidence available indicated tuberculosis as the most likely diagnosis and was made with the realization that the diagnosis was unproven

The pathological classification of pulmonary tuberculosis and the explanation of why the various types occur involves many considerations, included are the factors of bacillary dosage, resistance and sensitivity, both host and tissue, and the duration of the disease process The response to therapy is significant to the clinician In addition there are other considerations, some fact, some theory, all are interesting but beyond the scope of this presentation

Cavity Closure in Collapse Therapy The presence of cavitation constitutes a most significant indication for instituting collapse or extirpative surgical therapy Pinner defines anatomical healing of a cavity as complete obliteration of the lumen and disappearance by resorption or fibrous replacement of all tuberculous tissue alterations in the cavity [13] The apposition of the walls without uniting them by fibrous tissue may indicate healing roentgenologically and may result in reversion of the sputum from positive to negative, but does not satisfy the definition of anatomical healing In our experience it has been difficult to identify, with any degree of certainty, a scar or a fibrotic area as a healed cavity

The mechanism by which a cavity heals is a subject of controversy as is the question of whether or not bronchial closure is necessary or is even beneficial to the closure of a cavity It has been postulated that cavities heal by filling with granulation tissue and that there is regeneration of pulmonary tissue replacing the granulation tissue leaving no scar after healing is complete More probable, the healing is accomplished after apposition of the walls of the cavity and if the walls are free of a layer of caseous necrotic material A fibrin latticework is necessary upon which fibroblasts may proliferate and unite the apposed clean surfaces of granulation tissue It would seem, therefore, that anatomical healing would only follow complete evacuation of the cavity and apposition of the walls

Auerbach and his associates in an extensive study of cases having received no chemotherapy, noted that almost invariably bronchi communicating with cavities revealed the same tuberculous process as that seen in the adjacent cavity [1] These writers suggested that collapse therapy might aid in the process of bronchial occlusion by apposition of the bronchial walls and under proper conditions the bronchial walls would unite

firmly resulting in permanent closure of the cavity Following closure of the cavity there is absorption of air from the lumen contraction of the wall absorption of fluid from the caseous material and finally calcification of the inspissated material (Fig 3) Accompanying this process the wall of the cavity is converted into a zone of hyalinized connective tissue Such inspissated cavities are not infrequently seen although there is not unanimity of opinion as to the manner in which they are formed

Effect of Drug Therapy There have been few anatomical and histological studies of the effect of drug therapy on tuberculosis This is understandable because drug therapy regimens have changed at frequent intervals and newer agents are being developed Because it has been in use longer than others streptomycin has been studied more extensively than other chemotherapeutic agents used in the treatment of pulmonary



FIG 3 —Inspissated cavity in tuberculosis Note constriction of bronchus.

tuberculosis It is apparent from these studies that although there is no histological pattern that can unequivocally be associated with streptomycin therapy it would appear to exert its most beneficial effect upon surface lesions Mahon studied the effect of streptomycin in autopsy and surgical specimens in our laboratory and although unable to identify a specific effect of the drug he was impressed with the increased tendency toward healing of the lesions by fibrous replacement [8]

Auerbach and his associates noted that the 'closure' of cavities in streptomycin treated cases frequently was accomplished in a manner entirely different from closure in those patients not treated with streptomycin [9] These writers noted that the bronchi entering the cavity were lined by epithelium either squamous or columnar rather than the necrotic material or granulation tissue lining the bronchial walls of the untreated cases and that this epithelium extended along the cavity wall for a considerable distance The occurrence of epithelium lining a *tuberculous*

cavity in a patient not treated by streptomycin is rare indeed Accompanying the epithelialization of the cavity wall there was a decrease in the size of the cavity and an absence of the usual perifocal reaction surrounding the cavity The contents of the cavities became inspissated and the above writers raise the question as to whether or not such cavities with patent bronchi are potential sources of danger If they contain viable bacilli they are potentially dangerous and such residua should be extirpated Further study will clarify this problem and give statistical evidence of the occurrence of this "open healing" of cavities under streptomycin therapy

Extirpative Surgery The inability to culture M tuberculosis from stabilized lesions in resected tissue, even though organisms are demonstrable by smear and tissue sections, is generally recognized It is postulated by some that these organisms are not viable, by others that they were rendered not viable by drug therapy Still others report inability to culture the microorganisms from stabilized lesions from patients that have not received drug therapy and they too can demonstrate organisms by smear and tissue stains We have a series of 100 cases having received chemotherapy in which we were able to demonstrate acid-fast bacilli by smear or tissue stains but have been able to culture the organisms on artificial media or in animals in only 12 per cent It would appear that these organisms are not viable but we can only say that they are not viable for the type of media and the type of animals used, nor do we know that they will remain so for any given length of time if allowed to remain in their host Likewise, we are unable to say that they were rendered nonviable by the chemotherapeutic agent used Stabilized disease may break down, become active, and progress whether or not chemotherapy has been employed This seems to be much less frequent during the chemotherapy era There are no reliable criteria by which we can determine whether or not a given stabilized lesion will remain stabilized or will become active and progress The specter of activation, then, constitutes one of the more important criteria for extirpation of residual lesions

There is one other reason for extirpative surgery It affords an effective means of studying the effects of treatment Many of us recoil in horror at the suggestion that portions of a lung be removed for the purpose of study by the pathologist, yet would not hesitate to suggest mediastinal or pulmonary biopsy for the purpose of diagnosis or evaluation of treatment It is only by the thorough study of healed and healing lesions in the human host that we can hope to fill in the gaps in our knowledge of the natural history of pulmonary tuberculosis and the manner in which it is modified by various chemotherapeutic agents

There is still another group of pulmonary lesions that must be treated by extirpative therapy This group constitutes the lesions variously designated as round lesions, coin lesions, solitary lesions and the "spot" on the lung Our experience with this group of lesions is discussed elsewhere in detail Suffice that we have found that the most careful history, exhaustive laboratory studies, competent roentgenographic interpretation and the most astute clinical acumen too often give us nothing more than a shrewd guess as to the etiology of the lesion We have found too that age

is no infallible criterion in ruling out neoplasm for we have seen bronchogenic carcinoma in twenty five-year-old patients and pulmonary metastases in patients even younger We know of no means of establishing a diagnosis in this fascinating group of lesions short of extirpation.

Our observations are in agreement with the clinicians in that present extirpative surgery is a distinct advance in the treatment of pulmonary tuberculosis

Classification of Pulmonary Tuberculosis in Relation to Surgical Therapy *General* The classification of pulmonary tuberculosis in relation to its surgical treatment although lacking exactness, is a valuable aid in selecting cases and appraising results[4,17,29] There is generally no distinct demarcation from one phase to another the so-called types often progressing or regressing from one to another and in the aggregate representing a disease process with tendencies to form patterns upon which a forecast as to its course may be made with considerable accuracy The response to rest and chemotherapy is a significant factor in formulating predictions The meticulous study and recording of factual information concerning surgically excised pulmonary tissue is the best basis upon which to classify pulmonary tuberculosis in relation to surgical therapy

Classifying the disease process into types or phases, in relation to surgical therapy becomes from the practical viewpoint largely a matter of proper timing in the application of surgical procedures The designations employed have been caseopneumonic fibrocaseous, caseofibrous (the suffix indicating the nature of the predominating lesion), fibrous giant cavitation 5 or more centimeters in diameter as noted on roentgenographic examination tuberculoma and empyema Fibrocaseonodose is a term commonly employed by pathologists and generally includes the types designated as fibrocaseous and caseofibrous The categorizing of the disease process by the surgeon should preferably include factual data referable to its initial evidence course of the disease and the response to therapy When extirpative surgical methods are employed the histopathological examination permits definite classification of the disease at the time of surgical removal

Caseopneumonic Tuberculosis Caseopneumonic tuberculosis is not infrequently encountered as a surgical problem The characteristics are variable The process may be acute with severe clinical manifestations or of a more chronic nature with few and mild symptoms This latter variety blends into the group designated as fibrocaseous In the former pneumonia often of a lobar distribution is the initial clinical diagnosis and tuberculosis is not considered until resolution is noted to be slow or acid fast bacilli are found in the sputum This acute type is characterized by a sudden onset of symptoms evidenced by fever of 100 to 104° F chills and prostration occurring in an apparently previously well person who is now seriously ill The roentgenographic findings are those of fluffy diffuse lesions which are homogeneous The lesions are presumably exudative and resolve strikingly when treated with streptomycin and para-aminosalicylic acid or certain other chemotherapeutic agents As the severity of symptoms decreases excavation often becomes evident Bronchogenic dissemination is common and fibrosis is slow Prior to the chemotherapy

era, the clinical course was often rapidly downhill, surgical therapy was inappropriate, and artificial pneumothorax seldom useful because of the frequent advent of empyema Caseopneumonic tuberculosis remains a serious disease requiring urgent chemotherapy

During the early phase of the use of streptomycin, 35 patients initially classified as acute caseopneumonic were treated with extrapleural thoracoplasty [6] These patients represented those least likely to obtain favorable results from surgical intervention [11] Thoracoplasty, though employed relatively early during the course of the disease, was not applied until considerable resolution of the exudative lesions had occurred, with parallel improvement in clinical symptoms The rapid and excellent response to streptomycin permitted the patients to come to thoracoplasty early, averaging nine months from the onset of the disease [6] With increased ex-



FIG 4 —Acute caseopneumonic tuberculosis treated by thoracoplasty *A* December 8, 1945 Extensive bilateral involvement *B* May 21, 1947 One day prior to thoracoplasty, left Marked resolution of parenchymal lesions Male, white, soldier, age 33 Sudden onset with fever 101–104° F, November 8, 1945 Sputum positive for tubercle bacilli Bed rest for 14 months without chemotherapy resulted in considerable clearing of extensive bilateral parenchymal infiltration Improvement continued under four months of massive streptomycin therapy, totaling 420 grams Moderate untoward reaction to the drug Thoracoplasty, left, seven ribs, May-July, 1947 He is well and since January, 1950, has been working 40 hours a week as a hospital janitor Onset to thoracoplasty, 18 months

perience in the use of the chemotherapeutic agents, and the favorable response to their employment for long periods, six to eighteen months, the use of permanent collapse therapy relatively early in the disease process has been largely abandoned (Fig 4)

Fibrocaseous Tuberculosis The fibrocaseous type designates a phase in which the caseous element predominates, yet the fibrous component is a very appreciable part of the process In the surgically excised lung tissue lesions of the fibrocaseous type have been encountered more often than any other The onset of symptoms is more gradual and malaise less

evident than in the caseopneumonic variety The roentgenographic appearance is varied but usually is characterized by scattered ill-defined linear markings with diffuse or localized confluent soft areas of increased density Cavitation is evident as honeycombing or small to large areas of excavation The predominantly exudative lesions respond favorably though less rapidly than the pneumonic variety to the chemotherapeutic drugs Cavitation usually persists the tendency toward chronicity is considerable and surviving patients have long been regarded as eventual candidates for surgical collapse therapy The results of thoracoplasty have been generally satisfactory With the increasingly favorable results obtainable from chemotherapy surgical intervention is applicable earlier in the course of the disease than formerly practiced and extirpative surgical methods are now the preferable therapy (Figs 5 and 6)

Caseofibrous Tuberculosis This type represents the common chronic variety of pulmonary tuberculosis in which surgery especially thoracoplasty was widely employed prior to the advent of chemotherapeutic agents. The fibrous element in the disease process predominates and if complications or dissemination do not occur the process usually continues into the fibrous phase of chronic phthisis The symptoms lack severity A mild continuous fever is frequent with easy fatigue chronic productive cough and gradual loss of weight Cavitation is the rule with roentgenographic evidence of fibrosis Artificial pneumothorax has steadily been replaced by other forms of therapy as pleural symphysis is to be anticipated and cavities are more difficult to close because of the thickness of their walls[19] Surgical procedures other than thoracoplasty or extirpative measures are of doubtful value and the latter offers a shorter safer and surer road to recovery (Fig 7)

Fibrous The fibrous type of pulmonary tuberculosis is characterized by chronicity The essential roentgenographic features are retraction of the involved hemithorax, thick walled cavitation and displacement of mediastinal structures toward the involved side. The patient has usually known that he has had tuberculosis for several years and has developed a considerable degree of resistance to the effects of the tubercle bacillus The symptoms are often minimal and combined with a chronic cough Pulmonary function may be markedly reduced resulting in mild to marked dyspnea. Emphysema and fibrosis replacing large amounts of pulmonary parenchyma are characteristic Prior to the chemotherapy era such patients represented the residual or survivors of pulmonary tuberculosis Their lot was often years of varying degrees of invalidism with persistently positive sputum For a long time this was almost the only variety of pulmonary tuberculosis considered suitable for surgery and usually permanent collapse therapy such as thoracoplasty was recommended Such patients are still occasionally encountered and present problems in surgical management varying from the so-called good chronic to those whose pulmonary reserve has been so depleted as to make them an unsatisfactory risk for any surgical therapy Unchecked the progression of fibrosis may lead to an excessive work-load for the right side of the heart and cor pulmonale with right heart failure may result The tuberculosis may heal but death results due to the damage accompanying the healing process The

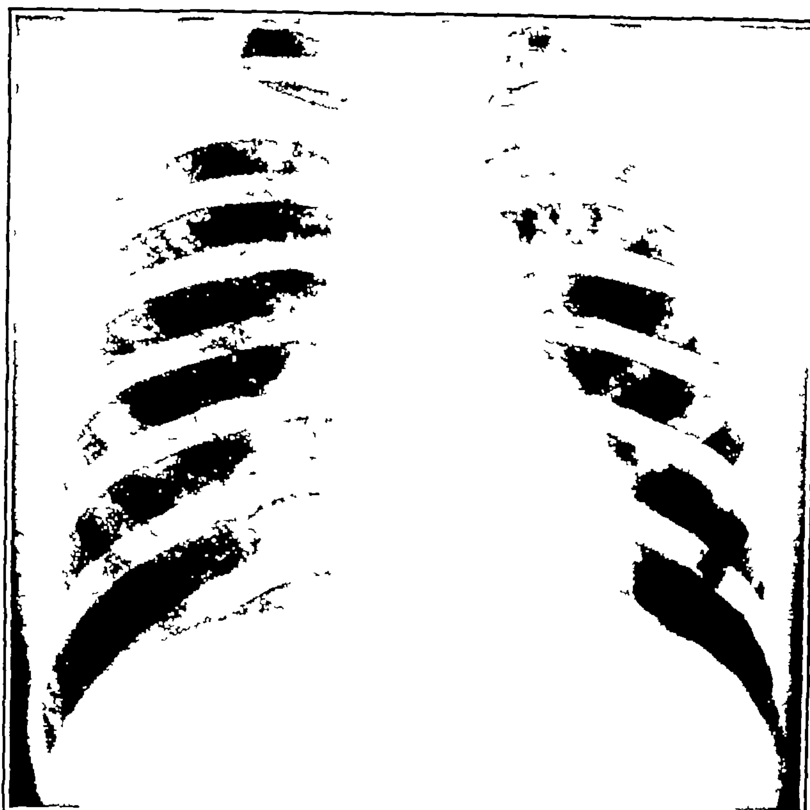
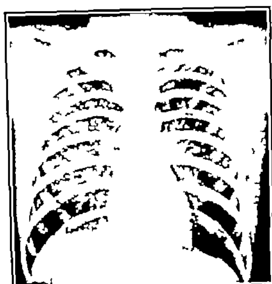




FIG. 5.—Fibrocaseous tuberculosis treated by thoracoplasty. *A*, April 8, 1949. Lesions, left upper lobe. Cavity present. *B*, April 17, 1951. Ten months post-thoracoplasty, five ribs, two stages. White, male, Army officer, age 30. Became ill with symptoms of moderate cough, chest pain, and fatigue early in 1949. He was hospitalized in April, 1949. At that time he was jaundiced and sputum was positive. Considerable clearing of lesions in left upper lobe followed streptomycin therapy administered in two courses, May-June, 1949 and June-August, 1950, with para-aminosalicylic acid added during the latter course. Thoracoplasty, five ribs, two stages, performed in June, 1950. He is well and has been working 20–40 hours per week since January, 1952. Onset to thoracoplasty, 14 months.



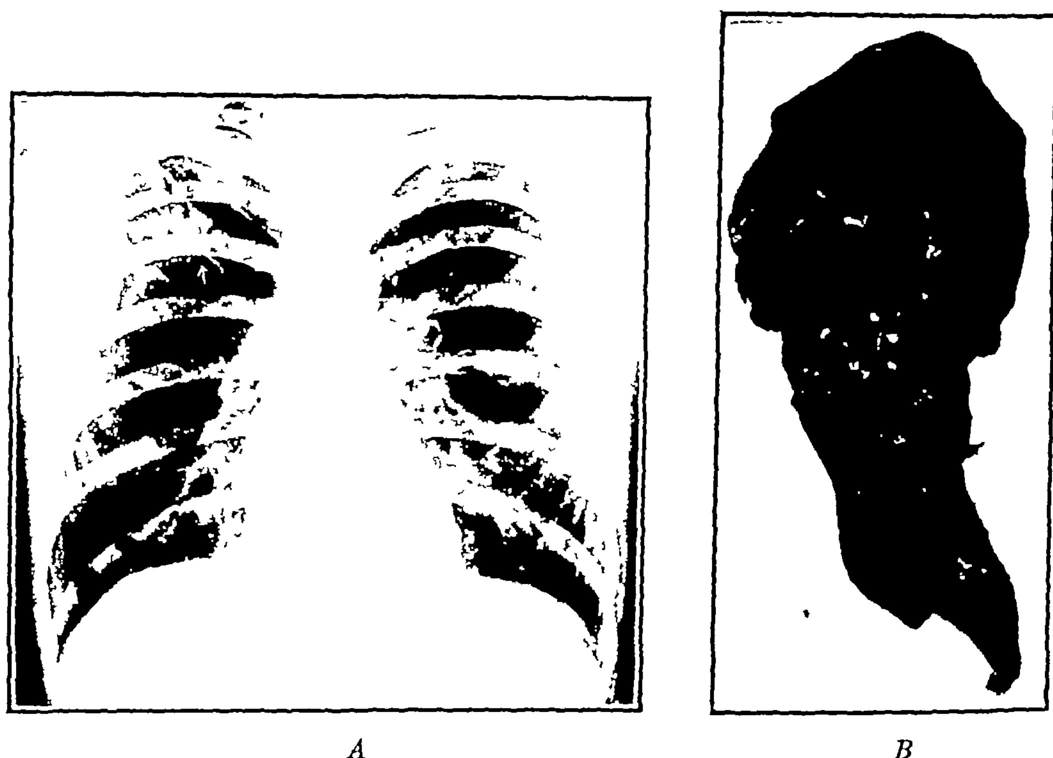
A



B

Fig. 6 —Fibrocaseous tuberculosis treated by lobectomy *A* November 14 1950 One day prior to lobectomy Cavitary lesions, right lower lobe. *B* Surgical specimen right lower lobe White, male, soldier age 27 Routine roentgenogram of the chest for recruitment in August, 1950 revealed a cavity in the right lower lobe and moderate surrounding parenchymal infiltration. Streptomycin 2 grams every third day and 12 grams of para aminosalicylic acid daily was started September 10 1950 and a right lower lobectomy and phrenemphraxis were performed November 15 1950 He is well and has been performing active military duty since May 1952 Onset to lobectomy three months. (Forsee courtesy of Amer Surg)

excellent results now being obtained with the use of appropriate chemotherapy and surgery has markedly diminished the incidence of this type of disease Extrapleural thoracoplasty has long been the favored surgical procedure in the treatment of fibroid phthisis and has given very satisfactory results Extirpative measures are, however, being employed with increasing frequency and effectiveness (Fig 8)



A *B*

Fig 7 —Caseofibrous tuberculosis treated by chemotherapy and lobectomy *A* March 6, 1952 White, soldier, age 36 Lesion, right upper lobe, detected on routine chest roentgenogram prior to separation from the Army, September, 1951 Patient was asymptomatic Sputum negative Chemotherapy such as streptomycin, 2 grams every third day, and para-aminosalicylic acid, 12 grams daily, from November, 1951 to March, 1952 without appreciable change in lesion Drugs continued for three months after surgery Exploratory thoracotomy, right, March 7, 1952 The right upper lobe contained a firm round mass 4 to 5 cm in diameter located in the central portion of the lobe Lobectomy was performed Tubercle bacilli were identified from the caseous center of the mass Culture negative for fungi and acid-fast bacilli Pathological diagnosis was tuberculosis, caseofibrous Patient is well *B* Surgical specimen Central location of lesion required removal of entire lobe

Giant Cavitation The presence of giant cavitation of the lung in pulmonary tuberculosis presents a serious problem and is a challenge to any method of surgical attack A cavity which roentgenographically measures 5 or more centimeters in diameter is arbitrarily considered as of giant size This classification is limited to single cavitation and does not include the total area of cavitation which may be present The incidence of patients with giant cavitation undergoing surgical therapy in our series

since 1947 has been approximately 8 per cent of those treated by thoracoplasty or extirpative surgery. The variety of surgical procedures employed to meet the problem of giant cavitation suggests that generally poor results may be expected with any method. No single procedure or method is highly effective. I am convinced that those problems of giant cavitation which can be effectively managed surgically are best met by joint extirpative and thoracoplasty methods (Fig 9).

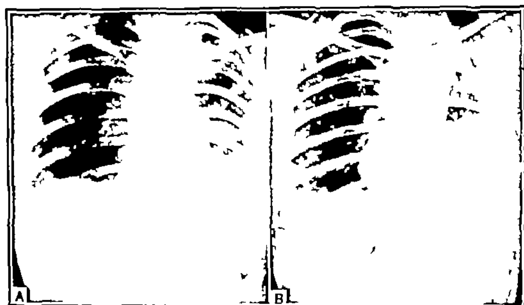


FIG 8.—Fibrous tuberculosis treated by thoracoplasty. *A* March 15, 1948. Mediastinal structures pulled to left. Left hemidiaphragm elevated. Lesions, left upper lobe are dense. Three cm. cavity in left apex. *B* August 8, 1949. Three months after thoracoplasty, left, five ribs, three stages. Good result. White, female, age 34. Duration of disease 16 years. Sputum positive. Thoracoplasty April-May 1948. Pulmonary function poor and vital capacity only 25 per cent of normal preoperatively. Streptomycin 224 grams. Hospitalized 15 months after thoracoplasty. Sputum consistently negative since operation. Pulmonary function has improved but she still has dyspnea on marked exertion; otherwise she leads a normal life.

Tuberculoma. *Definition.* The tuberculoma has been variously called the round focus, pulmonary focus, Assman focus, Simon focus and calcified pulmonary abscess. It represents the focalization of a tuberculous pneumonia by fibrous encapsulation, appearing as a rounded subpleural pseudotumor located in some portion of the lung. These tuberculous nodules are the result of a chronic inflammatory process of a granulomatous type which follows a characteristic pattern associated with but not the exclusive property of an infection caused by the Mycobacterium tuberculosis, e.g. infection with Coccidioides immitis or Histoplasma capsulatum can produce a nodule identical with those due to tuberculous infection. In our series of tuberculomas the size varied from 1.0 cm. to 6.0 by 4.5 cm.; the average size was 2.5 cm. They have been reported in every organ of the body except those which have natural tissue immunity to invasion by

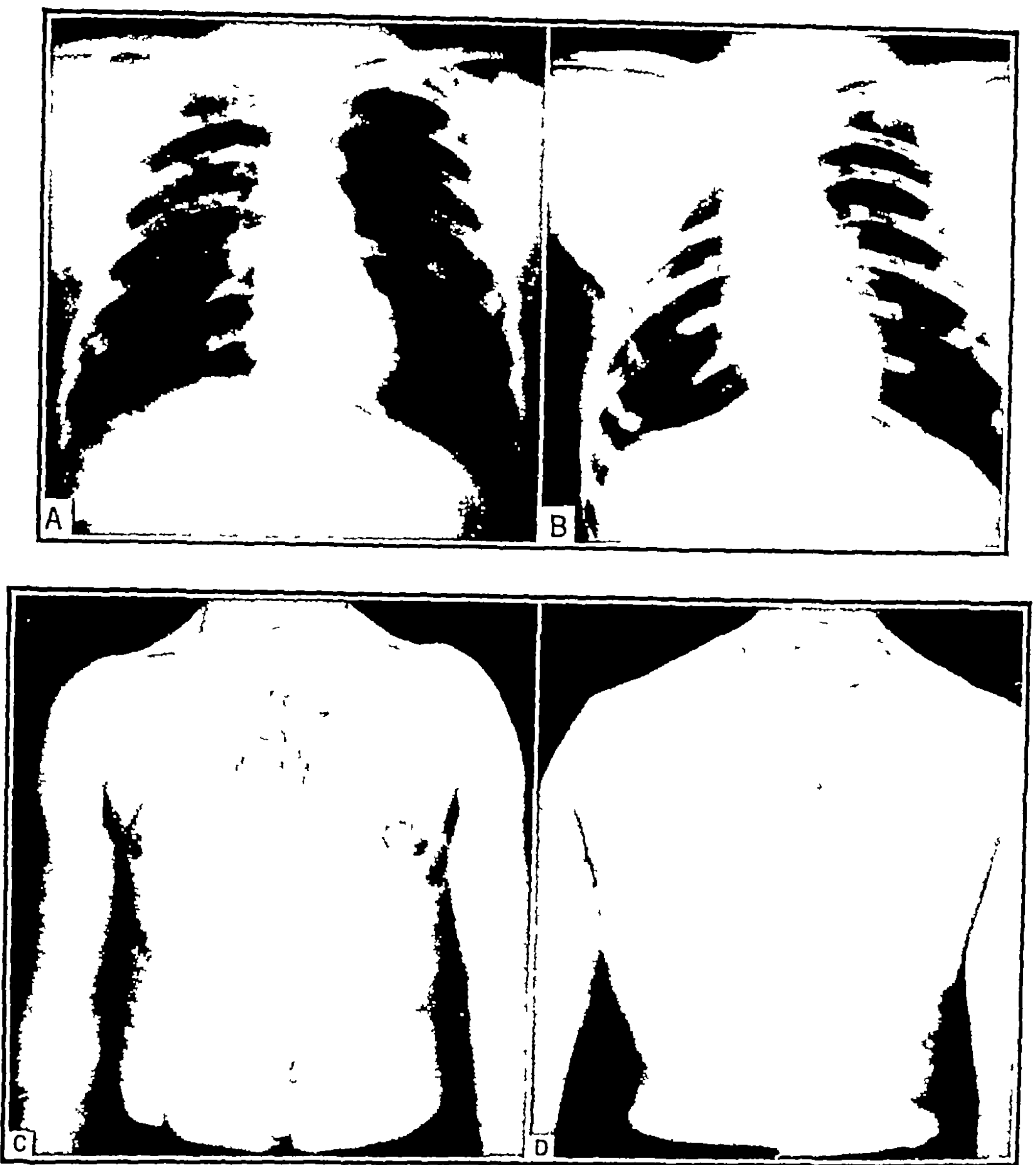


FIG 9—Giant cavitary disease treated by lobectomy and five-rib thoracoplasty *A* December 19, 1949 Giant cavitary disease, right upper lobe *B* December 23, 1950 Three months following right upper and middle lobectomy and two-stage, five-rib thoracoplasty *C* and *D* Front and back view of patient one year post-surgery No deformity White, male, soldier, age 21 On a routine chest roentgenographic examination, for admission to Officer Candidate School, September 21, 1948, parenchymal infiltration was noted in upper portion of right lung field Mild pulmonary symptoms were elicited Sputum was positive for tubercle bacilli He was hospitalized at Fitzsimons Army Hospital and elsewhere from September, 1948 to August, 1951 Cavitary disease, upper lung, noted early in 1949 Artificial pneumothorax was ineffectual Endobronchial tuberculous disease noted on bronchoscopic examination November 11, 1948 and appeared healed one year later Cavitation enlarged and persisted but had decreased to about 3 cm in size at time of lobectomy Streptomycin alone and later combined with para-aminosalicylic acid was administered over varying periods beginning in November, 1948 A first stage thoracoplasty, right, was performed July 21, 1950, right middle and upper lobectomy with second stage thoracoplasty performed August 11, 1950 Surgical specimen revealed endobronchial disease, numerous scattered nodular tuberculous lesions throughout both lobes from which tubercle bacilli were isolated and a 2 cm cavitary lesion, right upper lobe Total streptomycin, 181 grams Patient discharged one year after lobectomy, disease inactive Total hospitalization, 35 months Onset to lobectomy, 23 months He has been employed 40-50 hours per week as a construction labor foreman since April, 1952, 20 months after lobectomy (*C-D*, *Forsee*, *courtesy of Ann Surg*)

tubercle bacilli e g the pancreas There is an implication in the term pulmonary tuberculoma that it is a solitary lesion The chest roentgenograms give such an impression but after the lobe segment or wedge containing the tuberculoma is removed and examined grossly smaller similar fibrocaseous nodules were found in 60 per cent of the specimens in our series as satellites close to or at some distance from the main nodule So tuberculoma is a type of fibrocaseonodose tuberculosis in which one nodule is outstanding attracting the attention of the roentgenologist by its size its sharp outlines and the lack of surrounding parenchymal infiltration It may be found in any portion of either lung [3,19]

The Ghon nodule which is the encapsulated primary focus is rarely a surgical problem but the increasing occurrence of primary infection in adults, plus the tendency in this age group to delayed retrogression and calcification of the nodule often brings the primary round lesion to the attention of the radiologist and the surgeon

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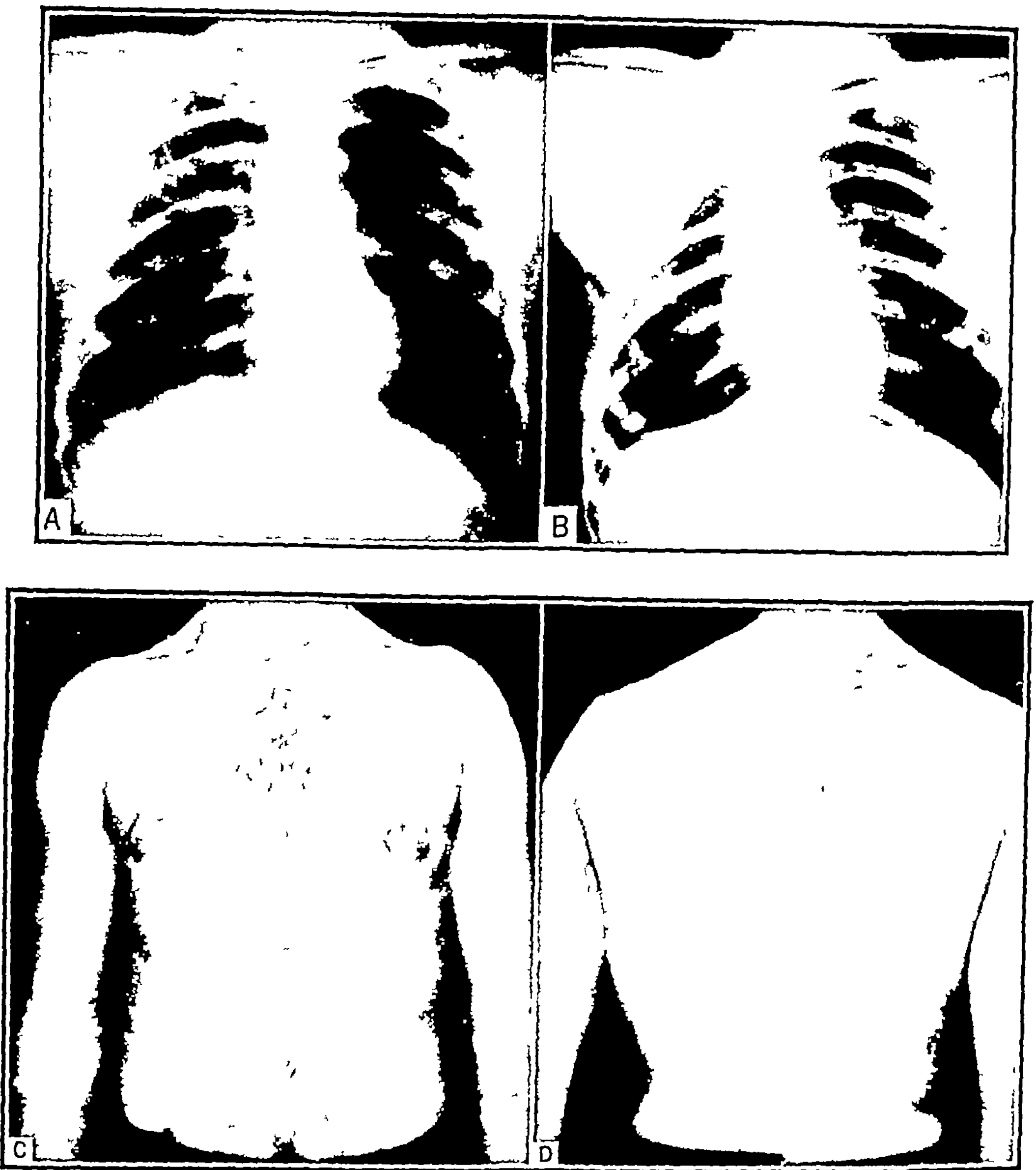


FIG 9 —Giant cavitary disease treated by lobectomy and five-rib thoracoplasty *A* December 19, 1949 *Giant cavitary disease, right upper lobe* *B* December 23, 1950 Three months following right upper and middle lobectomy and two-stage, five-rib thoracoplasty *C* and *D* Front and back view of patient one year post-surgery No deformity White, male, soldier, age 21 On a routine chest roentgenographic examination, for admission to Officer Candidate School, September 21, 1948, parenchymal infiltration was noted in upper portion of right lung field Mild pulmonary symptoms were elicited Sputum was positive for tubercle bacilli He was hospitalized at Fitzsimons Army Hospital and elsewhere from September, 1948 to August, 1951 Cavitary disease, upper lung, noted early in 1949 Artificial pneumothorax was ineffectual Endobronchial tuberculous disease noted on bronchoscopic examination November 14, 1948 and appeared healed one year later Cavitation enlarged and persisted but had decreased to about 3 cm in size at time of lobectomy Streptomycin alone and later combined with para-aminosalicylic acid was administered over varying periods beginning in November, 1948 A first stage thoracoplasty, right, was performed July 21, 1950, right middle and upper lobectomy with second stage thoracoplasty performed August 11, 1950 Surgical specimen revealed endobronchial disease, numerous scattered nodular tuberculous lesions throughout both lobes from which tubercle bacilli were isolated and a 2 cm cavitary lesion, right upper lobe Total streptomycin, 181 grams Patient discharged one year after lobectomy, disease inactive Total hospitalization, 35 months Onset to lobectomy, 23 months He has been employed 40-50 hours per week as a construction labor foreman since April, 1952; 20 months after lobectomy (*C-D*, Forsee, courtesy of Ann Surg)

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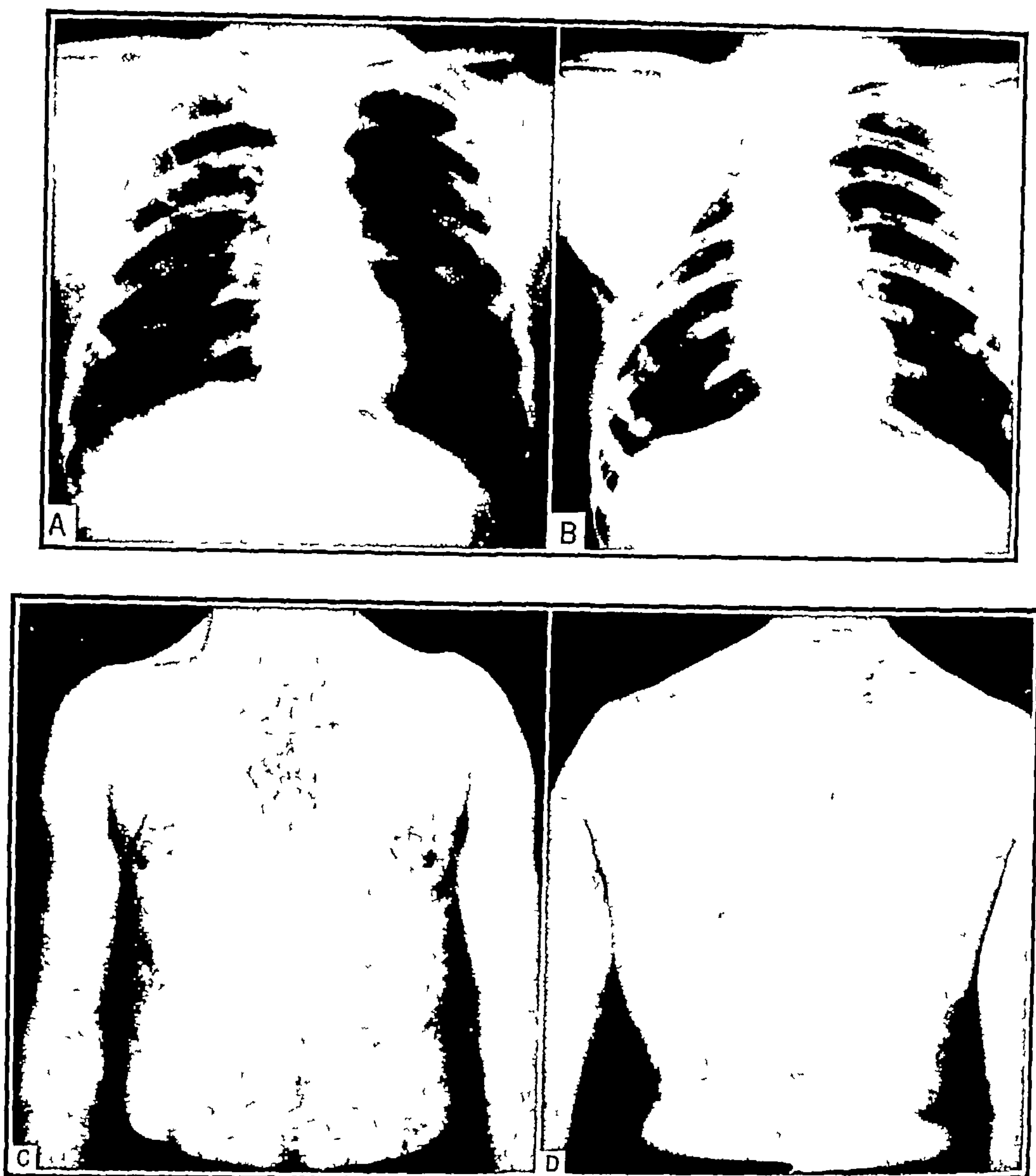


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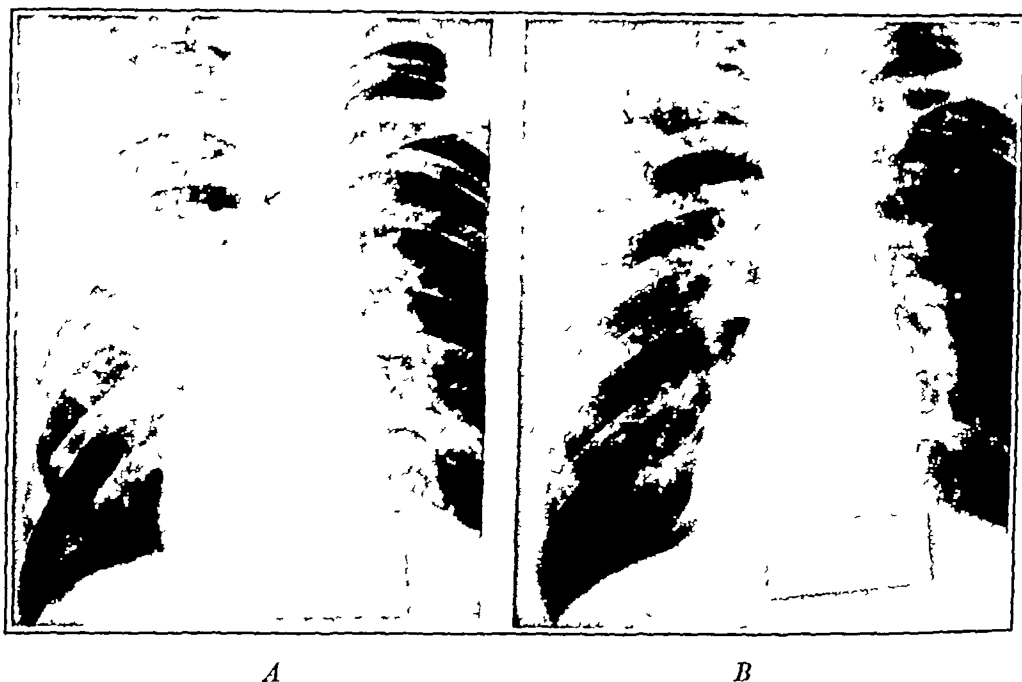
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bronchopneumonia with positive sputa, accompanied by the usual symptoms of an active tuberculous infection Under the usual bed rest regimen, and now with the addition of chemotherapy, the rather extensive pulmonary infiltration clears, leaving a rounded density much smaller than the original, involved area (Fig 10) (*b*) In a clear lung field an indistinct, faint, irregular, hazy spot or a cluster of small, several millimeter, densities appeared Symptoms as a rule are absent or there is minimal malaise, slight nonproductive cough, occasional 99° F temperature, negative sputa, and occasionally positive cultures are obtained from gastric washings This fuzzy area enlarges and increases in density, gradually rounding



A *B*

Fig 10 —Development of tuberculoma from extensive caseous bronchopneumonia *A* 1937 Caseopneumonic tuberculosis Patient improved under bed rest Sputum became negative *B* 1945 Round lesion, left upper lobe Sputum positive Left upper lobe lobectomy performed, 1945 Segmental resection would now be selected Patient is well and has carried on full time duties of a pathologist since 1947 (Mahon and Forsee, courtesy of Jour Thoracic Surg)

out until it finally becomes a sharply circumscribed round shadow Microscopically the process is a caseous pneumonia but smaller pulmonary units are involved, designated as a lobular or bronchiolar pneumonia, with each small unit encapsulating and fusing with its neighbor to produce a rounded nodule of approximately the same size as the originally involved focus (Fig 11) (*c*) The lesion begins as an extensive area of tuberculous bronchopneumonia which proceeds to cavitation In one-half of the patients the lesion was in the stage of cavitation when first detected by chest roentgenographic examination Occasionally spontaneously, but usually as a result of collapse therapy such as pneumothorax, pneumoperitoneum, or thoracoplasty the bronchus which drained the cavity becomes blocked, and

the cavity shrinks, its caseous contents are retained concentrated, and gradually the lucency of the cavity lumen disappears The result is a round focus not recognizably different at this stage from the similar rounded foci mentioned previously (Fig 12)

Fate of the Tuberculoma The fate of the tuberculoma is unpredictable The outlines of the consolidated alveoli filled with ghost epithelioid cells and identifiable in the microscopic sections may persist in this phase for months Ultimately the outlines of the previous alveolar and lobular structure and contained cells disappear and the center of the nodule is uniformly caseous and structureless The periphery is composed of concentric layers of fibrous tissue with some hyalinization and is infiltrated by plasma cells and lymphocytes Between the fibrous wall and the

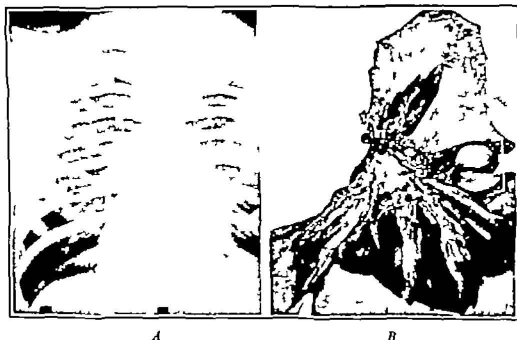


FIG. 11 —Development of tuberculoma in a clear lung A 1946 Round lesion appear on left in a previously clear area. Minimal symptoms. B Surgical specimer Left lower lobectomy performed November 1946 Tubercle bacilli demor strated in specimen Segmental resection would now be selected Patient i well He is a physician and has been engaged in the practice of medicin since 1930

caseous contents there is a narrow zone of epithelioid cells and occasiona typical Langhans giant cells but usually these giant cells appear shrunke and distorted The caseous center tends to inspissate and calcium phos phate is deposited in it This calcium deposition may be irregularl scattered through the caseous center or be deposited in concentric ring (Liesegang s rings) The calcification in our cases was never as general complete and dense as in a Ghon nodule rarely was decalcification re quired before the sections could be cut This target-like partially calcifie nodule is the ripe or mature tuberculoma and smears and cultures o

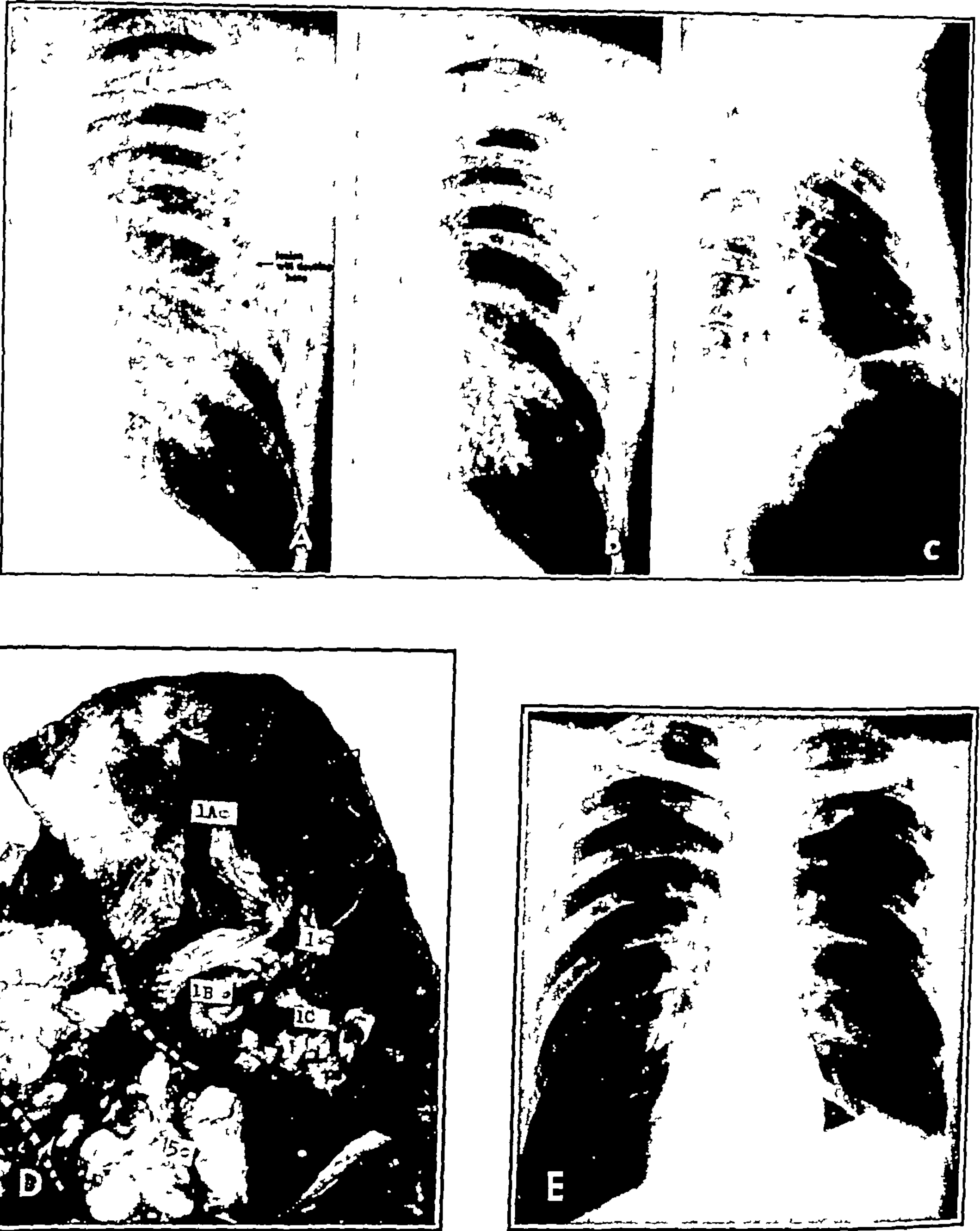


Fig 12 —Development of tuberculoma from tuberculous bronchopneumonia with cavitation, treated unsuccessfully by collapse therapy *A* 1942 Negative roentgenogram *B* 1944 Patient became ill, sputum positive, disease progressed and cavitation developed Artificial pneumothorax, pneumoperitoneum, and phrenemphraxis helpful but sputum remained positive *C* 1948 Rather large area of involvement has shrunk to a round lesion Right lower lobectomy performed Tubercle bacilli present in surgical specimen *D* Surgical specimen Tuberculoma seen on cross section *E* 1951 Patient is well and has been working full time as a clerk in a finance office since 1950

these lesions are negative for tubercle bacilli The ring-like calcifications may be visible in roentgenograms Such calcified fibrotic nodules may be mausoleums erected around dead bacilli (See Fig 57) Occasionally the caseous center liquefies uniformly and the nodule appears as a thin walled fibrous sac filled with diffluent pale yellow material more like pus than caseous material This type is the most unripe or immature tuberculoma and usually contains innumerable acid fast bacilli

Unfortunately the large majority of the solid tuberculous nodules are slow to calcify and mature the longest we have observed was eleven years when it began to soften and the sputum became positive They often show small areas of softening and liquefaction evidenced in the roentgenograms by small eccentric lucencies which may shift within the nodule when followed by serial roentgenograms It is rather characteristic that these lucencies are located at the junction of the caseous and fibrous zones and often appear in the roentgenographic shadow as peripheral slits following the curve of the wall of the nodule Smears and cultures of these irregularly softened nodules are usually positive for acid-fast bacilli There are always small patent bronchi or bronchioles in close proximity to the wall of the tuberculoma Often portions of the wall are quite thin With liquefaction close to a thin wall communication can be and is established with the bronchi with resulting escape of bacilli-containing material causing reactivation and dissemination of the tuberculous process (Fig 13)

Characteristically tuberculomas are located subpleurally in the periphery of the lung and bulge slightly beneath the visceral pleura Usually they have a white to yellow hyalinized plaque marking the fusion of the wall of the nodule with the overlying thickened pleura Those that do not quite meet the pleura usually have a dimpled pucker over them with a small white fibrous pleural thickening at the bottom of the dimple The hyaline plaque often extends as a 'V into the nodule and may be so dense that the nodule is grossly diagnosed as a chondroma Wedge excision is the preferable method for removal of the mature tuberculoma Satellite fibrocaseous nodules may lie close to or some distance from the main nodule occasionally fusing with the main nodule explaining the enlargement of some nodules Segmental resection or lobectomy is required to remove these lesions

The general characteristics of a tuberculoma are (1) a fibrous wall hyalinized in varying degrees (2) a caseous center of varying consistency from diffluent to dry granular and chalky (3) calcium deposition of varying degree and arrangement (4) anthracotic pigmentation depending on the degree of anthracosis in the rest of the lung and in the area of the parenchyma originally involved (5) hemosiderin pigment deposition, usually scanty and associated with the presence of granulation tissue in the lining (6) cavity formation of varying degrees, usually irregular slitlike and eccentric (7) a pleural cap of hyalinized fibrous thickening over the bulging dome or a dimpled area over the deeper tuberculoma.

Diagnosis In the majority of patients no history of familial tuberculosis is obtainable nor is there a history of contact It is always well to remember that there is more tuberculosis present than the roentgenograms indicate Postero-anterior roentgenograms of the chest will usually

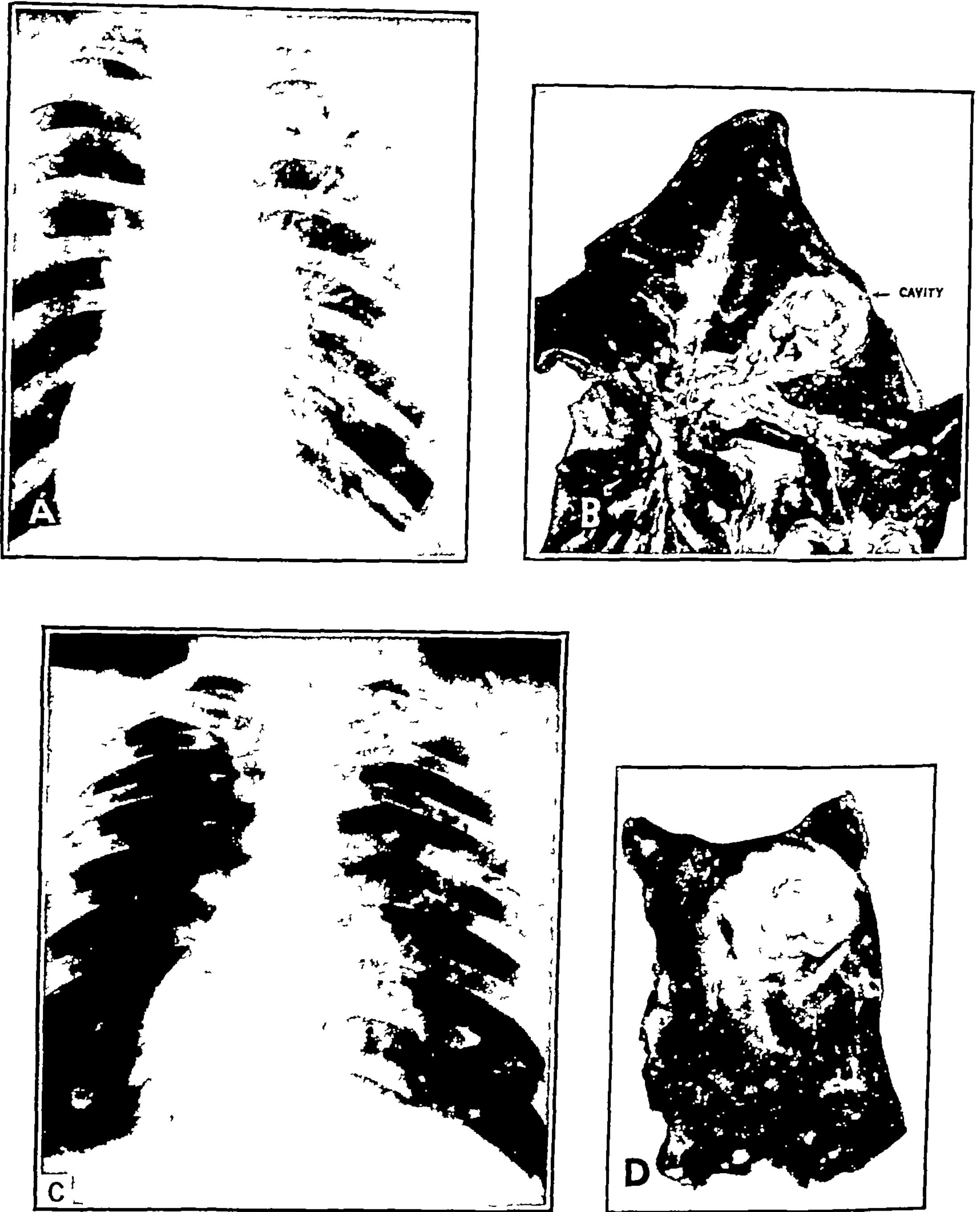


FIG 13 —Tuberculoma *A* Round lesion, right upper lobe Sputum and gastric washings positive for tubercle bacilli Roentgenogram, three years earlier, revealed parenchymal infiltration in first interspace, right The unpredictable nature of tuberculoma is demonstrated *B* Surgical specimen, right upper lobe Cavitary lesion of tuberculoma *C* Round lesion demonstrating areas of lucency peripherally, suggesting the breakdown of the lesion Sputum positive *D* Surgical specimen, tuberculoma, showing breakdown of the fibrous capsule Tubercle bacilli identified in the lesion (Mahon and Forsee, courtesy of Jour Thoracic Surg)

establish the presence of the nodule. Stereoscopic, oblique, lateral, and apical films may better visualize the nodule and aid in its localization Potter Bucky technique and tomograms help in the delineation of the nodule ascertaining its internal structure as to whether or not cavitation is present and in locating the depth of the lesion from the chest wall Fluoroscopy will show that the nodule does not pulsate and that it moves with the lung The value of bronchoscopy is chiefly negative As these nodules are usually at the periphery of the lung they are beyond the limited field of the bronchoscope If the nodule has cavitated and communicates with a bronchus bronchoscopy may determine which is the draining bronchus and by obtaining material for examination may lead to the establishment of the diagnosis of tuberculosis It also aids in determining if endobronchial tuberculosis is present. Bronchography is usually used to rule out other conditions as bronchiectasis and bronchial cysts Skin sensitivity tests are helpful The tuberculin skin test is almost always positive many only with second strength tuberculin (.005) Histoplasmin and coccidioidin tests may be equally positive. With the recent employment of the periodic-acid Schiff stain Histoplasma capsulatum is being identified frequently in those round lesions in which the tubercle bacillus is not demonstrable and the tuberculin skin test is negative This development is altering our previous concept regarding the tuberculous etiology of the lesion we have called the mature tuberculoma [14] We have not employed the needle biopsy technique as an aid in diagnosis or therapy Physical examination is usually negative No definite findings as a rule are present except in those cases of a residual nodule following extensive active tuberculosis The sedimentation test is usually normal or only slightly elevated

Differential Diagnoses The round pulmonary lesions found in surgical specimens removed since 1943 at Fitzsimons include (1) atelectasis of a nipple of lung parenchyma adherent to the parietal wall which has been strangled by adhesions (2) bronchial adenoma not visualized by bronchoscopy (3) echinococcus cyst (4) peripheral bronchogenic carcinoma (5) peripheral fibrosarcoma with no other primary site established (6) solitary metastasis of a renal adenocarcinoma (7) filled bronchiogenic cyst (8) arteriovenous aneurysm (9) calcified cast in a cystic bronchiectasis (10) chondrohamartomas these are also peripheral subpleural round lesions often with suggestion of central cavitation (11) nodular lesions of coccidioidomycosis their differentiation from tuberculoma depends on the recognition of the spherules in the tissue sections or by culture of Coccidioides immitis from the caseous contents (12) encapsulated interlobar tuberculous pleurisy (13) pyogenic lung abscess (14) histoplasmosis (15) neoplasm benign or malignant In spite of employing every possible diagnostic procedure to arrive at a correct preoperative diagnosis only their examination after removal establishes the correct diagnosis (Fig 14)

Surgical Management. There is no medical treatment that will clear up these nodules Streptomycin has no effect on the nodule and from assays of these encapsulated lesions it appears that streptomycin does not penetrate their fibrous wall They are potentially dangerous and may persist for years apparently unchanged and then cavitate breaking their

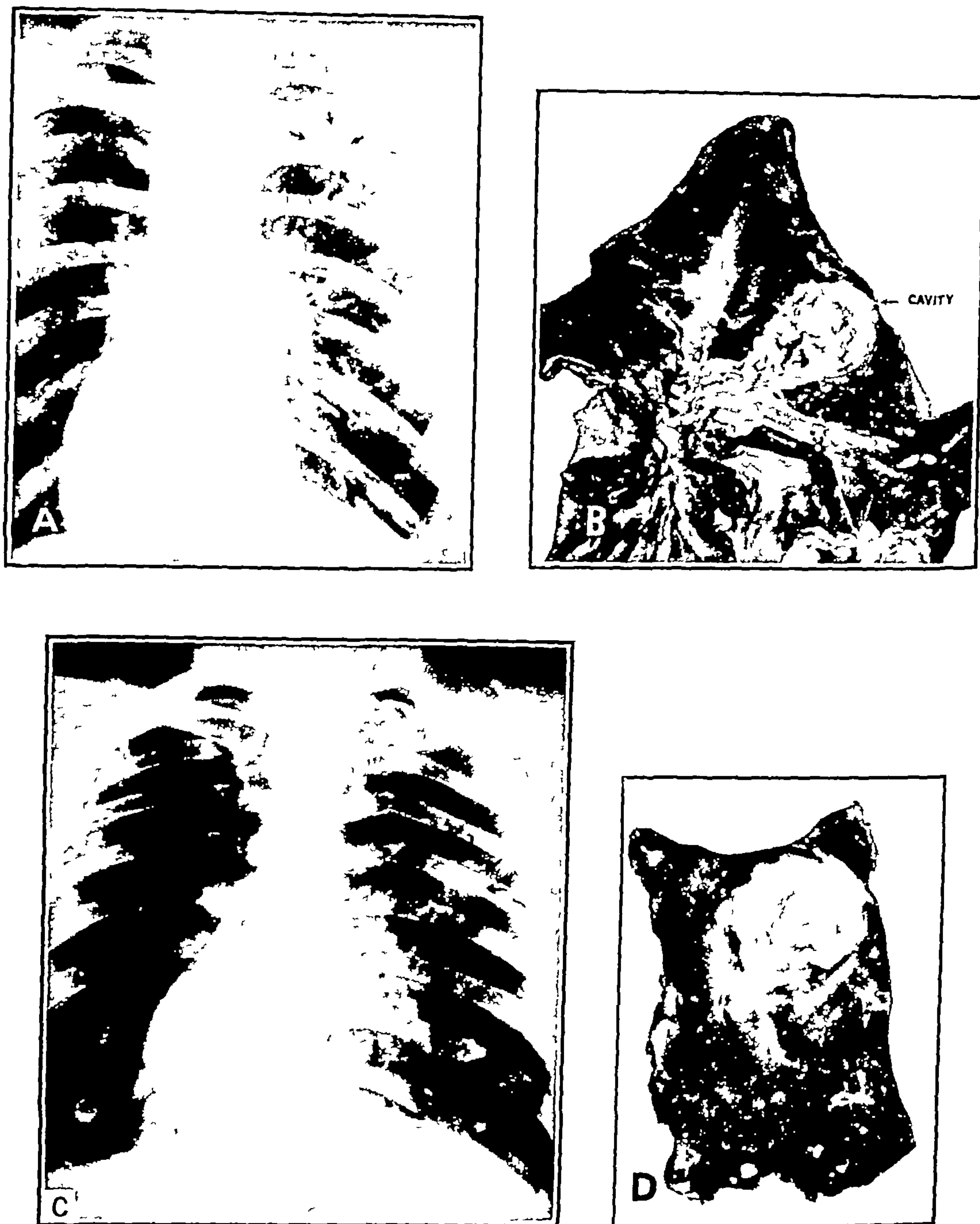


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of tissue to be removed A wedge excision is sufficient for the mature fibrocalcific tuberculoma A segmental or total lobectomy may be necessary where the area involved is too extensive for a wedge resection Enucleation is to be avoided due to the possible presence of microscopic tubercles in the adjacent parenchyma Experience in the surgical manage-



A



B

Fig 15 Legend on opposite page

ment of 81 tuberculoma lesions since 1943 has resulted in lobectomy being employed in 29 segmental resection in 6 and wedge excision in 46 Postoperative tuberculous empyema or dissemination of the tuberculous process did not occur In three-fourths of the patients the lesion was discovered accidentally by routine chest roentgenograms

Empyema. The development of empyema as a complication of pulmonary tuberculosis is serious and the results of therapy have long been poor The empyema may be tuberculous or pyogenic organisms may also be present in addition to the tubercle bacillus in the latter case it is classified as a mixed infection. The underlying parenchymal disease may be caseofibrous fibrocaseous fibrous or caseopneumonic. Empyema has become a rare complication following lobectomy 2.3 per cent and 1.3 per cent in segmental resection or wedge excision.

There interval reports from Fitzsimons Army Hospital 1937 1940 and 1950 indicate the developments relative to empyema.[1,4,7] In 1937 Leaver and Hardaway reported a mortality rate of 70 9 per cent in 24 patients with mixed infection empyema and 22 9 per cent in 35 patients having only tuberculous empyema In 1940 Aycock and Grow reviewed and

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FIG 15 —Tuberculous mixed infection empyema treated by thoracoplasty and streptomycin *A* March 2 1948 Spontaneous pneumothorax pulmonary cavitation and empyema, left. Thoracoplasty begun April 27 1948. *B* September 12 1949 Sixteen months after ten-rib thoracoplasty This 24-year-old male soldier gave a history of pneumonia in 1942, from which he recovered without complications. In January 1948 he noted undue fatigue productive cough blood-tinged sputum, and chest pain which was suddenly increased by severe dyspnea, hemoptyses, chills and fever and marked prostration. He was immediately hospitalized. Roentgenograms confirmed the presence of a spontaneous pneumothorax with approximately 50 per cent collapse of the lung and large cavitation in the left upper lobe. Daily thoracenteses with the removal of air and fluid accomplished moderate relief of symptoms. Closed tube intercostal drainage was established and discontinued prior to admission to Fitzsimons, February 27 1948. Thoracentesis was then carried out every other day with the removal of 500 to 1000 cc of thick, greenish fluid having a specific gravity of 1 021 which was positive on culture for acid fast bacilli. One-half gram of streptomycin was placed in the pleural space each time fluid was removed and 1 gram administered intramuscularly along with 300,000 units of penicillin daily The patient improved symptomatically with a sustained decrease in fever improved appetite, and a lessening of the accumulation of pus. A first-stage posterolateral thoracoplasty was performed. Further staged posterolateral thoracoplasties were accomplished until a ten-rib thoracoplasty had been completed May 18 1948, with removal of all of the first five ribs and long segments of the sixth to tenth ribs, inclusive. The pleural space was kept dry by frequent thoracenteses between operative stages. The exudative element of the pulmonary disease showed considerable resolution and by May 1948 there was no evidence of pleural fluid. Numerous gastric washings have since been negative for acid-fast bacilli. Frequent roentgenographic examinations of the chest revealed no evidence of parenchymal cavitation or infiltration, the pleural space was obliterated, and the patient was discharged one year after completion of thoracoplasty He remained well and has been working four to six hours daily for the past four years (Connolly and Forsee courtesy of Jour Thoracic Surg.)

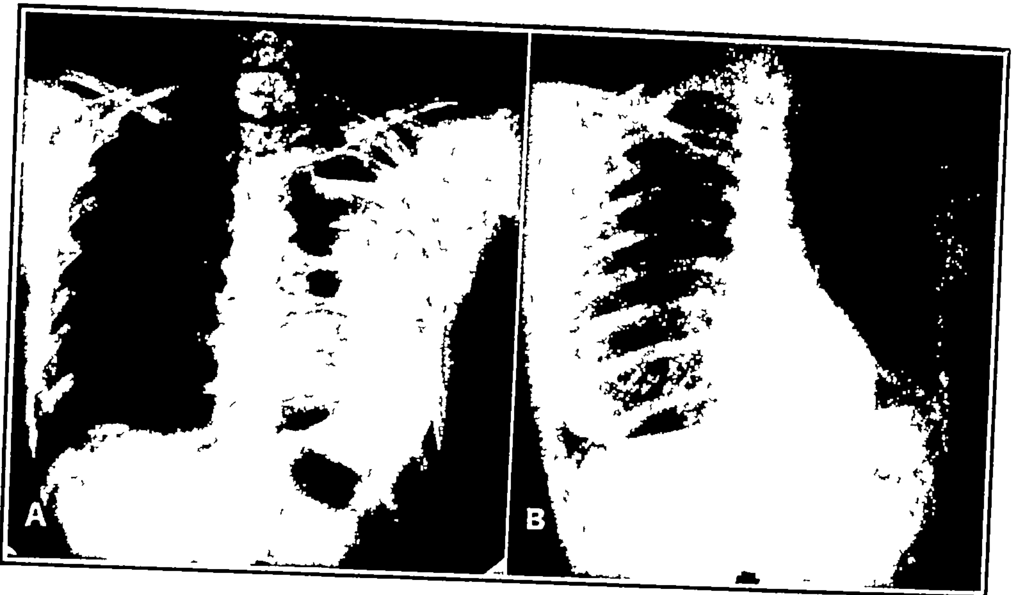


FIG 16 —Tuberculous empyema treated by decortication *A* January 27, 1948 Obliteration of most of the lung field, left, due to thickened pleura and empyema *B* September 9, 1949 Nine months after decortication Lung reexpanded Patient well *C* Surgical specimen of empyema sac White, female, age 24 Onset of disease was July, 1946 Artificial pneumothorax therapy was administered for two years beginning October, 1946, and was complicated by a superimposed spontaneous pneumothorax, empyema, and unexpandable lung Admitted to Fitzsimons Army Hospital, December 13, 1948 The pulmonary disease remained inactive She is well and has been carrying on her regular household duties since early in 1950 (Tempel and Forsee, courtesy of Mil Surg)

obtained follow-up data on 600 patients receiving artificial pneumothorax therapy Pleural effusion with a fluid level extending above the highest point of the hemidiaphragm developed in 199 patients (33.2 per cent) 79 per cent were serous effusions and 21 per cent were purulent exudates Ninety-five per cent of the purulent exudates occurred in patients with far advanced disease under artificial pneumothorax therapy The greatest single factor in the production of purulency was the development of a superimposed pneumothorax Of 19 patients who developed this complication 17 or 89 5 per cent died In far-advanced pulmonary tuberculosis several factors tend to favor the development of pleural effusion (1) A large area from which dissemination of the disease may occur or pleural reaction develop following collapse therapy and (2) pleural adhesions and secondary associated changes such as emphysematous blebs or bullae which may rupture producing a superimposed spontaneous pneumothorax and an acute pleuritis [3,10]

Connolly and I reported our experience with a consecutive group of 22 patients having tuberculous empyema treated by extrapleural thoracoplasty and streptomycin during the period December 1 1946 to August 1 1948 [4] The results were as follows In pure tuberculous empyema with parenchymal involvement disease inactivation occurred in 85 7 per cent The follow-up period averaged 18 4 months the shortest was thirteen months and the longest twenty nine months In the group of 15 patients having mixed infection empyema 4 are dead and 1 patient had active tuberculosis in the contralateral lung eighteen months following thoracoplasty In 10 patients the empyema space is obliterated and no reactivation occurred during an average follow up period of 24.5 months (Fig 15)

The changing concepts of therapy and management of pulmonary tuberculosis have resulted in the reduction of the incidence of tuberculous empyema The early abandonment of an unsuccessful therapeutic pneumothorax the decreased use of such therapy and success with the use of chemotherapeutic agents permitting earlier application of thoracoplasty or the surgical removal of tuberculous lung tissue are favorable trends in lessening the occurrence of this still frightening complication

Further development in the surgical therapy of tuberculous empyema includes the employment of decortication In our experience we have not been able to predict with a satisfactory degree of accuracy the extent of the adherence of the lung and the fibrous empyema sac The procedure of decortication has been employed in 55 patients and offers an added aid in many instances in the surgical therapy of tuberculous empyema (Fig 16) Decortication was often associated with other surgical methods such as thoracoplasty or extirpative procedures in the treatment of empyema Pleural pneumonectomy is advocated by some in the treatment of tuberculous empyema associated with considerable parenchymal disease [15] I have had no experience with this procedure and fortunately the incidence of tuberculous empyema has rapidly decreased in our experience during the past three years

Summary Pulmonary tuberculosis is becoming more and more a surgical disease in that chemotherapy brings about resolution of new exudative lesions permitting the relatively early surgical removal of the older

first thoracoplasty operations to relax the tuberculous lung tissue He resected small segments, 3 to 4 cm , of the second and third ribs anteriorly, or more, depending on the size of the cavity In 1890 Carl Spangler resected somewhat longer lengths of rib and called the operation "extrapleural thoracoplasty" These operations were abandoned as unsatisfactory because the number and length of ribs resected did not effectively collapse the diseased lung Ludolph Brauer of Hamburg, Germany, advised a much more extensive resection, and in 1907 Friedrich carried out the suggested operation by removing long sections, 10 to 25 cm each, of ribs two to nine inclusive, along with the periosteum and the intercostal muscles This procedure was soon modified by removing a segment of the first rib, leaving the intercostal muscles, and carrying out subperiosteal resection

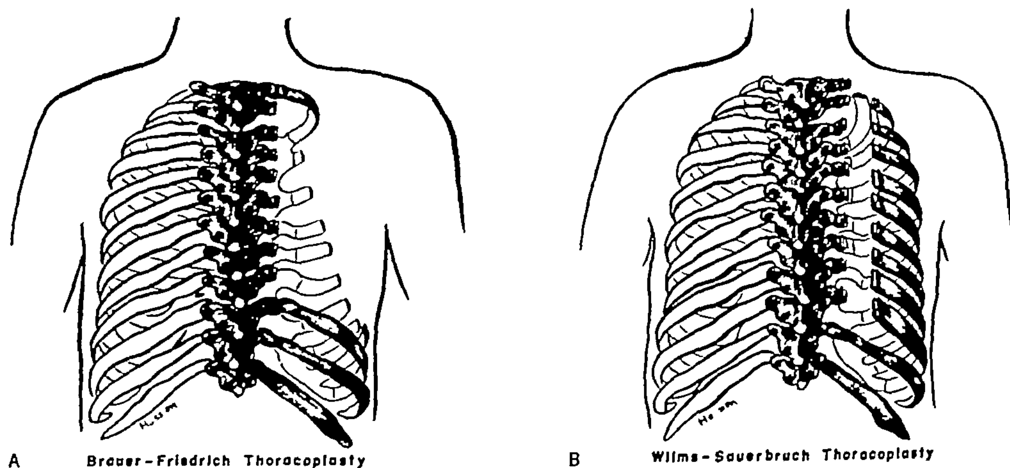


FIG 17 —Diagrammatic representation of early thoracoplasty *A* Original Brauer-Friedrich thoracoplasty Operation performed in one stage Mortality was high due to extensive loss of rib support with resultant paradoxical breathing *B* Paravertebral resection of ribs in the one-stage Wilms-Sauerbruch thoracoplasty

of the ribs, including long segments of the first to tenth ribs inclusive A total of as much as 200 cm of ribs were resected in a single operation The lack of bony support for the operated side resulted in the chest wall being markedly drawn in during inspiration and blown out during expiration, resulting in paradoxical respiration The displacement of the mediastinum to the opposite side, recognized as mediastinal flutter, magnified the disturbance of the cardiorespiratory physiology as evidenced by rapid, labored breathing, cyanosis, and ineffectual coughing Available therapy had little beneficial result The high mortality, 30 per cent, required further operative modification Under the leadership of Wilms, Sauerbruch, and Brauer, the staged paravertebral and subscapular extrapleural thoracoplasty operations were developed, which largely eliminated the hazards of the Brauer-Friedrich procedure, and gained widespread use (Fig 17)

Early Thoracoplasty at Fitzsimons Army Hospital The first extrapleural thoracoplasty performed in the treatment of pulmonary tuberculosis at Fitzsimons Army Hospital was accomplished by Major Wm H

Thearle in December of 1921 In a recent communication he states, "We resected in one stage the first eleven ribs from the transverse processes to the mid axillary region for the first four ribs and with a gradual reduction of the next seven These patients were in shock from the changed relations of the thoracic structures and they had paradoxical breathing to a degree dependent on the extent of the rib resection. I tried to combat this as much as possible by strapping the operated side of the chest with a layer of firm adhesive plaster My first 4 cases were all one-stage operations They required oxygen at once for their dyspnea They were all digitalized and given drugs for secondary anemia Obviously they had a stormy course and usually I had to stay up with them most of the night for the first week. Realizing the one-stage procedure was too severe a strain on these debilitated patients I then decided to do the operation in two stages with resection of the first four ribs at the first stage and the second stage in about three weeks when the patient had come back from the first operation I resected the first four ribs from the anterior axillary line to the transverse processes and resected the remaining seven ribs in a gradual extent so that only 3 or 4 inches of the eleventh rib was resected At the same time I switched to nitrous oxide analgesia Morphine gr ¼ was still used postoperatively and the chest was still held by adhesive strapping of the operated side until it was set in about six or eight weeks In 1926 I did several cases in three stages At the same time I started to use Cyclopropane as an anesthetic and felt it was much better than nitrous oxide analgesia "[21]

The experience at Fitzsimons during the early period was representative of the best results then obtainable and was summarized by Thearle in 1924[22] There were 35 patients treated and 7 or 20 per cent were clinically cured *i e* symptom free for at least one and one-half years with little or no sputum and able to do a satisfactory day s work. Six were greatly improved 3 had noted some improvement no change had occurred in 4 8 were still under treatment and 7 had died early in the postoperative period Empyema was a frequent complication

The experience at Fitzsimons from 1922 through 1930 was further reported by Bruns and Casper[5] Briefly 156 patients received 274 thoracoplasty operations in the treatment of pulmonary and pleural tuberculosis Eight and nine-tenths per cent or 14 of the patients died within seven days following operation Another 10 9 per cent died within three months a total early mortality rate of 19.8 per cent This includes 26 operations performed for tuberculous and mixed infection empyema Of the 92 patients operated upon during the period 1922–1928 21 died within three months following operation Of the 71 surviving patients the disease became arrested in 43 or 46 7 per cent of the total Twenty five years later the mortality rate per patient for thoracoplasty performed for pulmonary tuberculosis exclusive of empyema has been reduced to less than 1 per cent while the danger of death from a stage of thoracoplasty is about 1 death in 400 operations. This is a reflection in part of improved surgical and allied techniques but principally indicates the presently improved general condition of the patient in comparison to the desperate surgical risk patients of 1920–1930 plus the benefits of chemotherapy The late

deaths among 313 patients treated by thoracoplasty, 1947–1952, have been few, a total mortality rate of approximately 10 per cent

Periods in Development of Thoracoplasty at Fitzsimons Army Hospital In general there have been three periods of development of thoracoplasty at Fitzsimons The first period was that just described, this continued, with frequent changes of operative technique, until 1935 During the period 1935–1939 the operative procedure of staged operations became well standardized A one-stage, five-rib thoracoplasty was frequently and effectively employed Apicolysis as advocated by Semb was often applied also [22] The third period, 1940–1946, was characterized by abandonment of Semb's apicolysis, and standardization of an operation employing the technique and methods advocated by Alexander [2] The increased use of whole blood transfusion during operation, the availability of greatly improved anesthetic methods, the adequate quantities of sulfa drugs, and penicillin after 1944, and streptomycin since 1947 have vastly improved operative surgical results

Long Term Results Certain data are available from these three periods which warrant emphasis Active pulmonary tuberculosis has long been characterized as a disease with some degree of permanent disability among those who survive Ninety per cent of the surviving patients treated by thoracoplasty, 1926–1946, are receiving 80 to 100 per cent disability compensation The work status of the surviving patients is noted in Table 2 (Graph I) The small number of patients who have reached the goal of full time work is amazingly low, less than 10 per cent. The challenge is great to provide complete rehabilitation, and restoration of a mental and physical condition wherein a pension or disability benefit is unnecessary and undesirable The total advances in the field of tuberculosis during the past seven years, of which the surgical aspects are a brilliant part, bear fair promise of achieving this goal

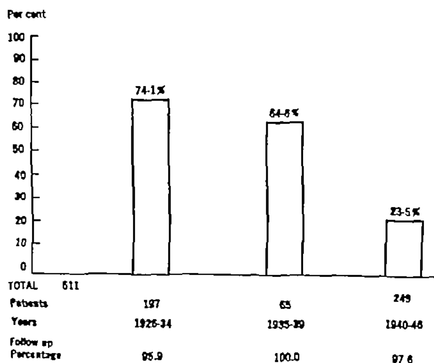
First Stage Upper Phase Extrapleural Thoracoplasty The first and second ribs are entirely removed, except the posterior part of the neck of the first rib The third rib is usually completely removed also, if a small anterior remnant is left it is removed at the second operative stage The incision is long and placed high, beginning at the level of the second rib posteriorly, midway between the vertebral border of the scapula and the spinous processes of the vertebra It is carried downward periscapularly, gradually curving laterally, and anteriorly, beneath the inferior angle of the scapula with the arm and shoulder elevated, along the course of the sixth rib to the midclavicular line The underlying chest wall muscles are exposed Skin towels are applied and stockinette is an excellent material for this purpose The auscultatory triangle, formed by the trapezius, rhomboideus major, and the latissimus dorsi muscles, is identified The tissue in the auscultatory triangle is incised, the cleavage plane beneath the rhomboid muscles is identified and the index and third fingers placed beneath these muscles The trapezius muscle is deliberately incised, and bleeding vessels individually clamped as pressure is maintained by fingers placed beneath the muscles The division of the muscle extends throughout the length of the incision The rhomboid muscles are treated in a similar manner. Transfixing sutures are applied for ligation of the bleeding

vessels in the upper angle of the incision Attention is now directed to division of the lateral and anterior portions of the latissimus dorsi and anterior serratus magnus muscles The index and middle fingers are inserted beneath these two muscles and with the scalpel small portions are incised first of the latissimus and after its complete division of the ser

Table 2 Work Status of Surviving Patients Treated by Thoracoplasty Fitzsimons Army Hospital, 1926-1946

				Report by Work Status					
				Full Time		Part Time		Not Working	
Period of Operation	No of Survivors 1948	No Reporting	Total	No	Per cent	No	Per cent	No	Per cent
1926–1934	57	41	41	3	7 3	14	34 1	24	58 5
1935–1939	23	22	22	4	18 2	10	45 5	8	36 4
1940–1946	192	157	157	26	22 0	41	26 1	80	51 0
TOTAL	272	220	220	43	19 5	65	29 5	112	50 0

Graph I Extrapleural Thoracoplasty Deaths. Fitzsimons Army Hospital, 1926-1946 5 to 25 Years After Operation



ratus anterior The transected vessels are individually ligated with non absorbable fine cotton or silk suture Catgut suture material has not been employed in thoracoplasty operations in the absence of infection during the past seven years. Wide exposure is obtained by the division of these four muscles through the length of the long incision

The scapula is elevated posteriorly and laterally, exposing the areolar tissue between the scapula and ribs This tissue is easily separated by the fingers, thus exposing the digitations of the serratus magnus from the upper five or six ribs These serrations blend, and the muscle is separated by the insertion of the finger or an instrument through the muscle, thus separating it into small segments Two clamps are applied, one above the other, and the segments of muscle are divided The muscle ends are tied with a transfixing suture This process is continued upward until the muscle is divided along its attachment to the second rib The intercostal nerve branches emerging from the inferior border of the ribs are usually preserved The serratus posterior inferior muscle is elevated and divided close to its rib attachments, bleeding vessels being individually clamped and ligated. A wide exposure of the rib cage is thus accomplished, and the next step is to identify the ribs

The excellent facilities now available demand that haste be avoided in carrying out thoracoplasty The strictest attention to meticulous hemostasis is mandatory Hemostats with fine grasping points occlude a minimum of tissue other than the bleeding vessel Compression of the divided muscle by the fingers from its under surface permits the surgeon and the assistant to carefully clamp each bleeding vessel The clamping of large amounts of adjacent muscle leads to its necrosis and favors infection

Despite references indicating that palpation of the first rib is simple and definite, I have found that the inexperienced frequently mistake the second for the first rib This difficulty may be decreased by noting the large and strong attachment of the serratus muscle to the second rib and it is often the highest rib which is distinctly palpable The presence of a cervical rib should be noted before operation by studying the roentgenogram. Confirmatory evidence of the removal of the first rib is obtained by noting the subclavian vessels which are readily brought into view after the removal of the first rib The ribs are removed in the order, third, second, first

Careful avoidance of opening the pleura is essential in rib resection during thoracoplasty Stripping the rib of its periosteum, which allows a subperiosteal resection, is a simple process if two rules are observed First, avoid the use of sharp periosteal elevators Second, keep the instrument firmly against the rib while freeing it of its periosteum The periosteum is incised along the rib midway between its upper and lower exposed surfaces The periosteal elevators, preferably the Alexander or Matson instrument, is used to separate the periosteum from the rib The lower surface of the rib is freed first, and with his fingers the surgeon may elevate the rib, and continue the separation of the periosteum from its under surface The upper edge of the rib is then freed from the attached muscle fibers and periosteum

With the rib freed over a wide lateral area, attention is directed toward the anterior and posterior ends of the rib. The removal of a small segment, 2 to 3 cm , of the freed lateral portion of the rib facilitates the removal of the anterior and posterior portions No attempt is made to preserve the continuity of the rib, and its division permits greater ease in its subsequent removal The underlying pleura is protected with gauze from perforation by the cut end of the rib The anterior end of the rib is gently elevated,

the serratus anterior and pectoralis muscles retracted and the periosteum and attached muscles separated from the rib by firm pressure on the periosteal elevator until the costochondral junction is reached The rib is transected at this junction Although the third rib is generally removed in its entire length an anterior segment in selected cases to aid in the preservation of pulmonary function may be left Attention is next directed to the removal of the posterolateral segment of the rib It is grasped with the left hand slightly elevated and the periosteum carefully separated from the rib The Sanderson elevator is especially adaptable in separating the muscle fibers from the rib at its posterior extremity The ligamentous attachment between the rib and transverse process is identified and as the rib is depressed this attachment is cut with blunt scissors. A small bone gauge is inserted into the space created between the rib and transverse process and by the application of gentle pressure the ligamentous attachments are separated When freed the rib is removed by disarticulating it from the corresponding vertebra, thus the entire posterior extent of the rib is removed This same method is applied to all ribs resected except the first The second rib is resected in the same manner as the third All of the second rib is removed

The removal of the first rib constitutes the most difficult technical problem in the first stage thoracoplasty The method of its removal which has been the safest, easiest and most efficient in my experience has been as follows Adequate exposure is absolutely necessary and retraction of the scapula in an upward direction appreciably facilitates exposure The first rib is palpated and of course this is made easier after the removal of the third and second ribs A blunt periosteal elevator rather than a scalpel is used to incise the muscle attachment and periosteum and to separate these structures from the rib The sharp lower border of the rib comes into view and the separation of the intercostal muscles and periosteum is then carried out along this inferior border and under surface of the rib The second step is the clearing of the superior border and upper surface of the rib This is carefully accomplished by a blunt periosteal elevator As soon as a length of 3 to 4 cm of the rib is cleared the index finger of the left hand is carefully inserted beneath the rib The finger is used as a guide and a protection against injuring the brachial plexus and subclavian vessels A 1 to 2 cm segment of the lateral portion of the first rib is resected and a sponge is placed beneath the resected end to prevent perforation of the pleura The anterior end of the rib is grasped with the left hand gently elevated cleared of muscles and periosteum to the costochondral junction and resected The attachment of the scalenus anterior muscle on the upper surface of the first rib is an important landmark, with the subclavian artery immediately posterior and the subclavian vein at the anterior attachment of the muscle The brachial plexus and subclavian vessels tend to fall away from the rib thus protecting these structures from injury After the removal of the anterior end of the rib the posterior end should be grasped with the left hand or suitable bone-holding forceps gently elevated and cleared of periosteum and muscle attachment The posterior end of the rib is in close contact with the following important structures the eighth cervical and first thoracic nerves and the sympa

thetic nerve trunk The rib is separated from the transverse costal ligament and is not disarticulated from the vertebra but transected across its neck

The transverse processes of the vertebrae other than the first are transected This is ordinarily accomplished after the rib resections are completed The sacrospinalis muscle is retracted, the process exposed, cleared of muscle, and the tendon attachments are cut with blunt pointed scissors.

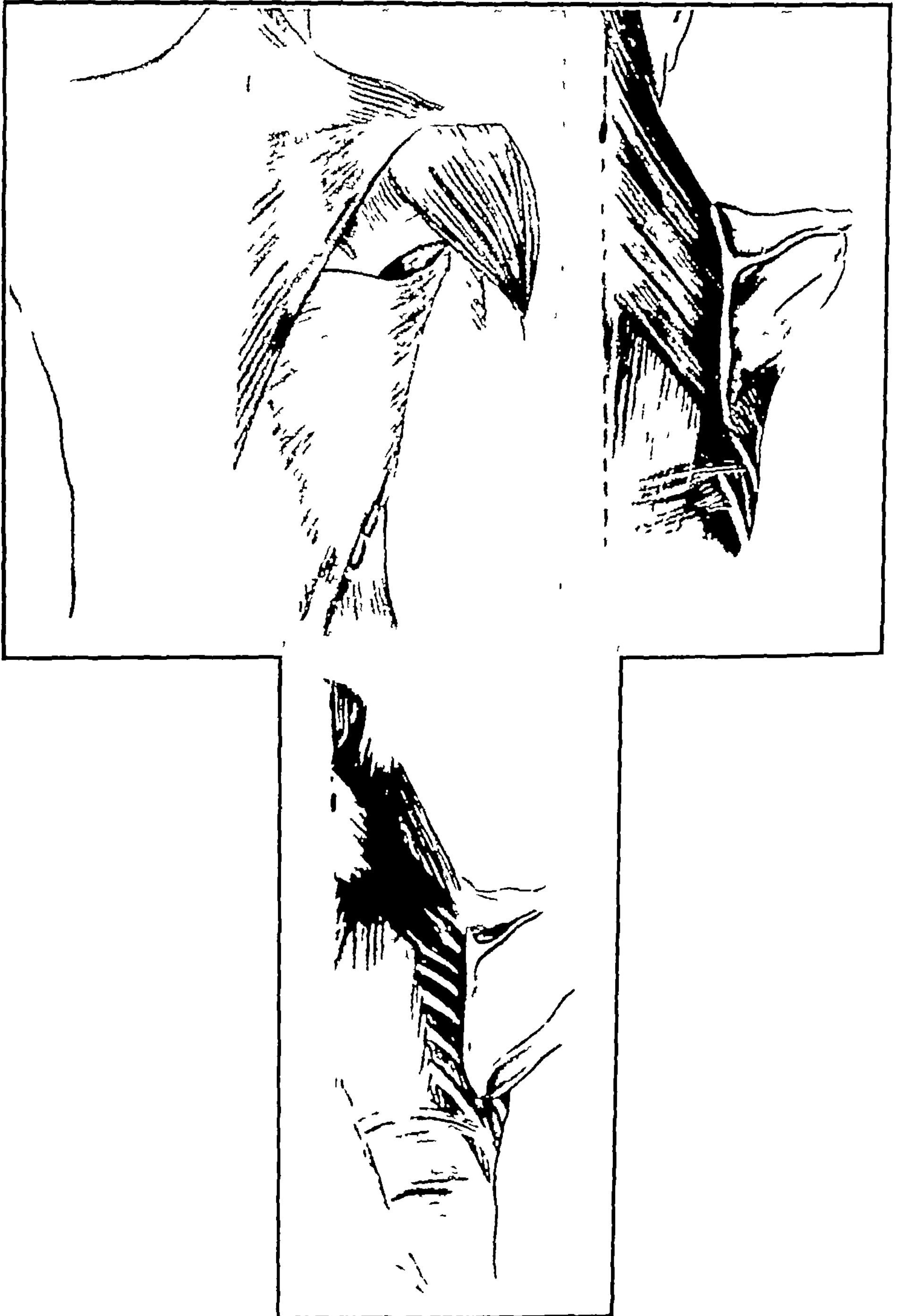


Fig 18 —Muscular structure of the thorax concerned with extrapleural thoracoplasty

The large Sauerbruch rongeur is used to transect the transverse process Ordinarily 1 to 2 cm of bone is removed Bleeding from the bone end is controlled by pressure

The wound is carefully inspected Any bleeding vessels are ligated The severed chest wall muscles are sutured in layers using fine cotton or silk with interrupted sutures being placed ½ to 1 cm apart No drainage is employed Sterilized mechanics waste makes a very suitable dressing which is covered with gauze and adhesive plaster (Figs 18 19 and 20)

Second Stage Upper Phase Extrapleural Thoracoplasty The interval between the first and second stages of operation is a maximum of three and a minimum of two weeks. This interval is selected for two reasons. First, it is sufficient to permit the patient to recover and regain strength from the preceding operation Second it is insufficient to permit the regeneration of bony tissue to interfere with collapse of the chest wall The operative scar of the first operation is excised except for its upper 3 to 4 cm throughout the length of the incision The underlying exposed chest wall muscles are incised along the course of the incision Suture material from the previous stage which is severed at this operation is removed Bleeding vessels are dealt with as in the first stage The fourth and fifth ribs are identified This is easy as the uppermost intact rib is the fourth Serum and fluid which have collected since the first stage are evacuated from the subscapular space thus permitting effective chest wall collapse free of pocketing Laxity in careful hemostasis in any stage of thoracoplasty operation is unwarranted The collection of blood in the subscapular space to aid in the collapse of the underlying diseased lung or in decreasing the size of the hemithorax has possibly been misconstrued to mean that haste in performing thoracoplasty operations permit a relaxation of rigid hemostasis This is dangerous moreover with meticulous hemostasis there is still sufficient serum from the large area of incised muscle to furnish adequate fluid for this purpose

The subperiosteal removal of the fourth and fifth ribs is carried out in the same manner as described above for removal of the second or third rib The anterior resection of the ribs is carried to within 3 to 4 cm of their costochondral junctions If the third rib was not removed to its costochondral junction and its anterior segment not considered essential to aid pulmonary function this segment is removed before the fourth and fifth ribs are resected The corresponding transverse processes of the vertebra are removed as described in the first stage The closure of the wound is accomplished by layer closure of the muscles with interrupted fine cotton or silk suture Drainage of the wound is not practiced This standard form of second stage operation is on occasions varied to include the resection of the sixth rib In the few instances in which a five-rib thoracoplasty is the complete definitive thoracoplasty contemplated the resection of the lower third of the scapula as originally recommended by Holman to promote compression of the lung is practiced (Fig 21)[14]

Third and Fourth Stage Thoracoplasty The standard posterolateral thoracoplasty employed as an independent procedure is a three-stage seven-rib thoracoplasty In the third stage the sixth and seventh ribs are resected in the same manner as described for the other ribs except the

first, with the anterior transection being accomplished so as to leave an anterior segment averaging 4 to 6 cm in length The lower three-fourths of the scar of the previous operation is excised The underlying chest wall muscles are incised throughout the length of the incision Rigid hemo-

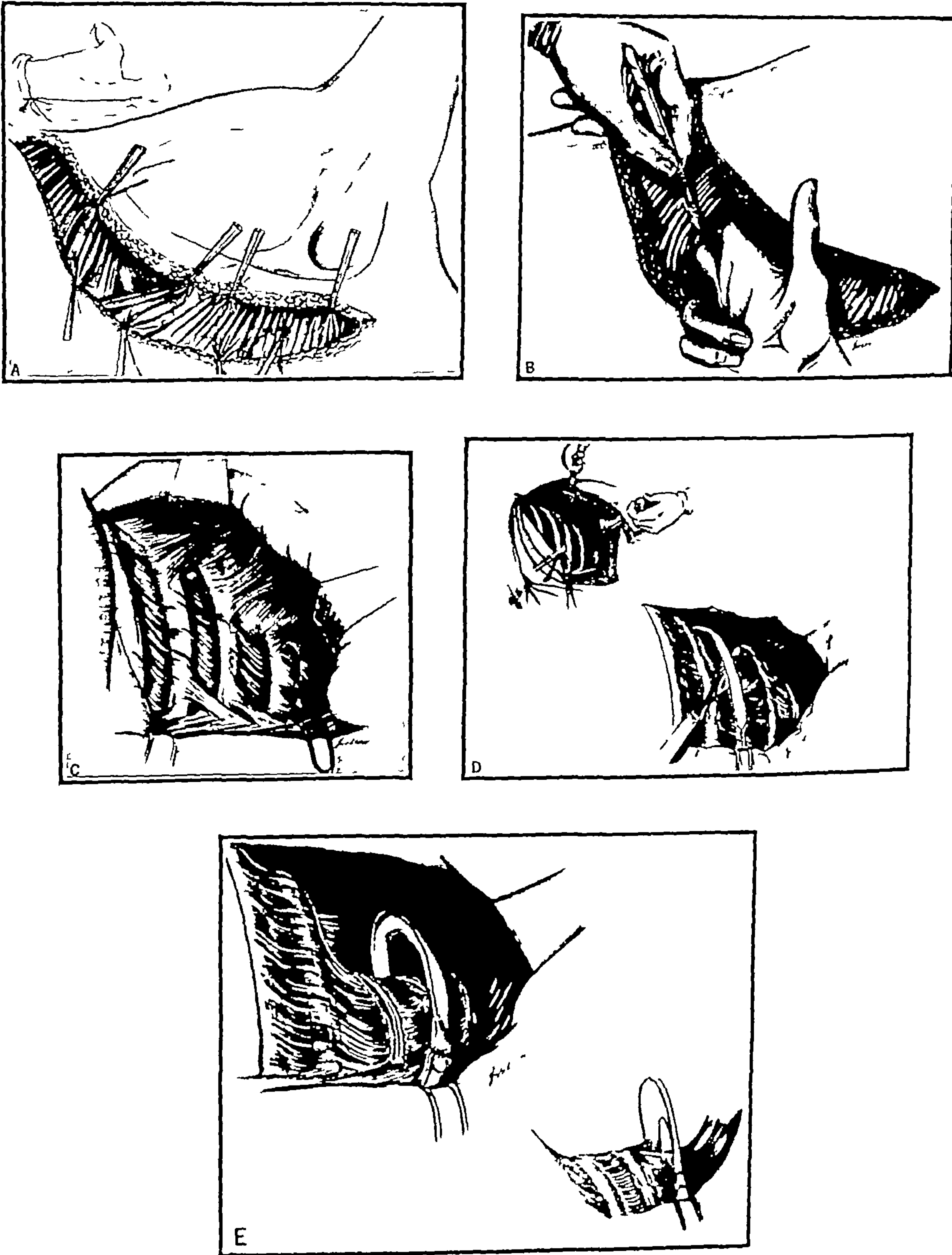


Fig 19 Legend on opposite page

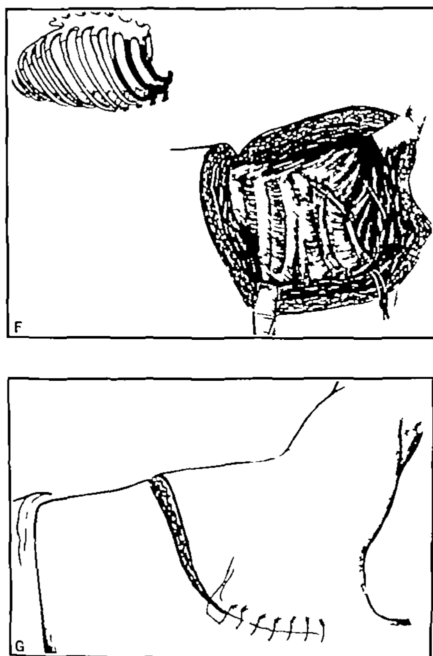


Fig 10 —Extrapleural thoracoplasty first stage. *A* The incision and exposure of outer layer of chest wall musculature. *B* Incising outer muscle layer Surgeon's fingers beneath muscle compresses bleeding vessels, and aid in their identification so that individual vessels may be clamped and ligated. *C* Chest wall muscles have been incised exposing the rib cage and digitations of serratus anterior muscle. *D* Digitations of serratus anterior muscle severed. Third rib being denuded of its periosteum Note Periosteal elevator hugs the rib *E* Third rib has been removed and second rib is being made ready for resection. Lower insert shows first rib ready for resection. *F* Upper three ribs removed. Wound ready for closure Muscle layers are approximated with interrupted fine silk or cotton suture The wound i not drained. *G* Wound being closed.

stasis is essential It is unnecessary to expose the subscapular space, and drainage of the wound is not employed Occasionally the eighth rib is resected in this stage, the length of rib removed is approximately the same as that of the seventh rib. A fourth stage operation is employed principally in the treatment of tuberculous empyema The eighth rib, if not previously removed and the ninth, tenth, and occasionally the eleventh ribs are removed subperiosteally, disarticulating the ribs at their vertebral

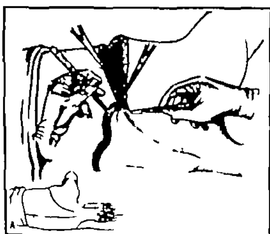


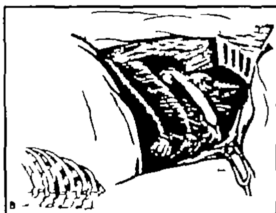
FIG 20 —First stage, upper phase, thoracoplasty showing ribs and second and third transverse processes removed

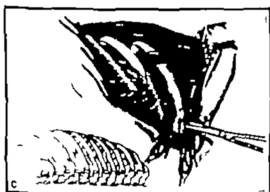
First stage thoracoplasty—Ribs 1–3—with transverse processes

attachments and dividing them anteriorly between the midclavicular and the anterior axillary lines The incision for the fourth stage may be through extending the scar of the previous operation, which is the usual method, or a new posterolateral incision may be made Again drainage of the wound is not practiced The second, third, and fourth stage operations are generally accompanied by a greater degree of pain postoperatively than is the first stage Injection of the area of the intercostal nerves with procaine and similar agents have been employed to reduce postoperative pain, but their benefit, in our experience, has been doubtful

Chemical agents are not applied to the stump of resected ribs to prevent regeneration The disarticulation of the head and neck of the rib from the vertebra probably decreases the tendency of regeneration as compared to the leaving of a posterior stump of rib The regenerated ribs form a firm support to the side of the thorax and are considered beneficial therefore attempts to delay or prevent regeneration are not practiced







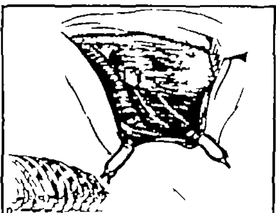


FIG. 21 —Extrapleural thoracoplasty second stage *A* Excision of scar from first stage thoracoplasty *B* Anterior stump of third rib is shown and the fourth rib is partially denuded of periosteum Extent of rib resection of first stage thoracoplasty is depicted. *C* Segment of fourth rib has been removed. Ligamentous attachment between rib and transverse process being severed. *D* Fourth and fifth ribs have been resected posterolaterally The exposed anterior rib ends will be transected to within 3 to 4 cm. of costochondral junction and wound will be ready for layer closure of incised muscles. The extent of rib resection after a two-stage five-rib thoracoplasty is depicted.

The effectiveness of thoracoplasty is dependent on several factors some of which are not thoroughly understood As thoracoplasty is employed principally for the purpose of effecting cavity closure a working rule which has been found satisfactory is to remove at least two ribs below the lower level of the cavity as noted on roentgenographic examination In

rare instances in which thoracoplasty is carried out for non-cavitary disease and evidence of considerable lower lobe involvement, a complete eight-to-eleven-rib thoracoplasty may be desirable Such extensive operations, except for tuberculous empyema, however, have been so largely replaced by excisional surgery that less than 1 per cent of our patients, exclusive of empyema, have been so treated during the past seven years In tuberculous or mixed infection empyema, in which thoracoplasty is employed to obliterate the entire pleural space, the complete nine-to 11-rib thoracoplasty is frequently employed

Anterior Stage Thoracoplasty The former practice of adding an anterior operation months later to supplement a posterolateral thoracoplasty because of failure of cavity closure is obsolete and with an adequately performed standard posterolateral thoracoplasty it is not necessary The anterior stage, if elected, should be in the plan of thoracoplasty application from the beginning, and should follow the second stage usually within ten days The approach is preferably through an anterior axillary incision extending upward to the lateral border of the pectoralis major muscle 3 cm below the clavicle, and downward below the level of the nipple Careful hemostasis is secured, the pectoralis major muscle is retracted medially and anteriorly, and the attachments of the pectoralis minor muscle to the ribs incised The entire anterior surface of the rib cage from the fifth intercostal space upward is exposed. The anterior rib ends of the first, second, and third ribs are resected subperiosteally The costal cartilages of the first three ribs are removed while the anterior ends of the fourth and fifth ribs are resected, including the costal cartilages The wound is closed in layers with fine cotton or silk interrupted sutures, and without drainage The effectiveness of the anterior procedure is best demonstrated in the thoracoplasty treatment of giant cavities, and in tuberculous empyema

In our experience, lobectomy has been a much more effective means of treating patients whose cavitary lesion had not been closed by a seven-rib posterolateral thoracoplasty Revision thoracoplasty and cavernostomy for the treatment of similar cavitary lesions have been discarded by us in favor of extirpative surgical methods

Revision Thoracoplasty The failure to accomplish cavity closure as a result of thoracoplasty presents a difficult problem An operative procedure designed to improve the collapse of the lung by removing the regenerated ribs, and resecting portions of ribs not previously removed, has often been considered as the best means of accomplishing the closure of such cavitary lesions Such revision thoracoplasty is carried out by excision of the previous thoracoplasty scar, and exposing the regenerated ribs The order of rib removal may vary Preferably the upper ribs should be removed first The revision thoracoplasty operation is, in my opinion, a procedure which is no longer warranted if an adequate primary posterolateral subscapular thoracoplasty is performed Revision thoracoplasty is a much more traumatic operation than a primary thoracoplasty Further, if cavity closure does not follow thoracoplasty, lobectomy or pneumonectomy are more effective measures than revisional thoracoplasty Since 1947 revisional thoracoplasty for the treatment of cavitary disease in the absence of empyema has been carried out only three times

Accidents Occurring During Thoracoplasty By the very nature of a thoracoplasty operation certain accidents related to technique may happen The prevention of such accidents is of course the responsibility of the surgeon Postoperative bleeding is except in rare instances of unrecognized blood dyscrasias a reflection of haste and lack of proper hemostasis at the time of operation Blood vessels of a large caliber except the subclavian internal mammary, and intercostal vessels are not encountered in thoracoplasty operations and such large vessels are not in a properly performed thoracoplasty subjected to ligation If the intercostal vessels are injured they should be doubly ligated by a transfixing suture on each end of the vessel If the internal mammary vessels are injured similar management is recommended I have never witnessed injury of the subclavian artery during the course of thoracoplasty Two patients in our series suffered a laceration of the subclavian vein during the removal of the first rib Firm pressure with gauze was applied the rib removed and in 1 patient the laceration sutured In 1 the early postoperative period was complicated by an apparent spread of the disease to the lower lobe due probably to hesitancy in carrying out the usual postoperative coughing regimen In the other patient there was no apparent ill-effect Injury to the brachial plexus has fortunately been rare Only 1 of our patients has suffered any permanent injury These accidents are largely avoidable and may be minimized by wide exposure of the operative field gentleness in the operative maneuvers and hugging the rib with the periosteal elevator especially the first while denuding the rib of its periosteum and attached muscles. A rib widely exposed is an easy rib to remove

Producing a pneumothorax by the perforation of the pleura is again an avoidable accident The surgeon experienced in the performance of thoracoplasty operations should deplore an incidence of this accident in excess of 1 per cent It is most apt to occur during the separation of the periosteum posteriorly at the articulation of the rib with the vertebra anteriorly near the costochondral junction or during the removal of the first rib Should the pleura be opened the opening should be closed and the lung reexpanded seldom will it be necessary to discontinue the operation If the rent in the pleura cannot be closed a large 45 F catheter should be inserted intrapleurally with its exit preferably through an interspace anteriorly and not from the operative incision The advantage of endotracheal anesthesia in thoracoplasty operations is particularly evident in such situations In the absence of a contralateral pneumothorax there has been no serious ill-effect during the past seven years in instances in which the pleura was opened if endotracheal anesthesia was used The late ill-effects have not been so free of complications If this accident occurs in the presence of a contralateral pneumothorax a much more serious situation is present Again the benefit of regularly employing endotracheal anesthesia is considerable The immediate aspiration of air from the contralateral pneumothorax is indicated if the rent is not rapidly and successfully closed with reexpansion of the lung on the side of the accident

Indications for Extrapleural Thoracoplasty The indications for extrapleural thoracoplasty in the treatment of pulmonary tuberculosis have

undergone frequent revisions, and constant efforts to discover the pr time for its application in relation to the phase of the disease process been exerted The indications emphasized by Sauerbruch and his temporaries in the early history of thoracoplasty were (1) unila disease, (2) fibrous type of tuberculosis, (3) rigid mediastinum, (4) cap heart, (5) youth, and (6) good general resistance These criteria were followed at Fitzsimons Army Hospital A less rigid case selection vailed, and no patient has been denied the chance of benefit despite being a poor or desperate surgical risk In 1936 I wrote, "Thoracopl has three rather specific indications First, in cases with upper cavitation when pneumothorax is impossible, and with an uninvo contralateral lung, or at least a contralateral lung with disease contr by compression therapy, second, in pneumothorax cases with uns factory pulmonary compression due to adherent lung or extensive ple adhesions, or in cases with rigid-walled cavitation which has resisted l pneumothorax and phrenic exeresis, and third, in the treatment of c plications of pneumothorax therapy, especially that of a purulent exu or untimely obliterative pneumothorax"[13] These indications have g ually been altered to embrace the acceptance of thoracoplasty as a mary procedure without first attempting artificial pneumothorax thera Efforts have constantly been applied toward improving the timing of application, so that thoracoplasty has gradually become very much elective operation rather than one of desperation. The principles invol in the indications for thoracoplasty were not, however, appreciably alte until the advent of streptomycin

In January 1947, streptomycin became available in adequate qua ties, and the indications for extrapleural thoracoplasty began to unde unprecedented changes The experience during the period 1947 to 1 has so altered our previous concepts as to the indications for thoracopla that they are no longer tenable, except in the treatment of tuberculous mixed infection empyema Its use as a space closing operation for tensive unilateral disease treated by extirpative surgery is regularly ployed In instances wherein extensive unilateral disease is present pneumonectomy refused by the patient, a three-stage, seven- or eight- thoracoplasty is recommended Primary thoracoplasty as the surg procedure of choice in uncomplicated pulmonary tuberculosis is, in recent experience, being employed in only about 10 per cent of patie treated surgically The substitution of extrapleural pneumothorax plombage for primary thoracoplasty is not recommended

Bilateral Extrapleural Thoracoplasty The surgical technique in lateral thoracoplasty does not differ from that of unilateral thoracoplas Seldom does a bilateral thoracoplasty exceed the removal of five ribs each side and we have rarely employed this method of therapy Extir tive surgical measures on one side and a five-rib thoracoplasty on the o posite side has occasionally been accomplished

Closed Intrapleural Pneumonolysis. *General* This is an excelle surgical procedure for severing adhesions between the partially collaps lung and the parietal pleura The method was originally devised by t late H C. Jacobaeus of Stockholm, Sweden.[17] My experience with tl

operation began in 1030 when collapse therapy methods were beginning to be used on a wide scale [10,12,14] My interest has continued unabated but the rapid decline in the use of artificial pneumothorax therapy since the advent of chemotherapy has almost eliminated the need for performing closed intrapleural pneumonolysis. During the past three years we have performed the operation on only 11 patients

Operation A pneumothorax with sufficient space for instrumentation is a prerequisite The technique of Matson using two instruments a thoracoscope and a cauterizing instrument employing the high frequency current for electrosurgical division of the adhesions is excellent [15] This requires two small openings through the chest wall The instruments popularized by Corvllos and by O Brien are equally satisfactory * Clear visualization of all adhesions and their site of attachments to the chest wall and lung is essential before any attempt at cauterization is warranted Local infiltration procaine anesthesia plus morphine 0 01 gram intravenously is the anesthesia of choice The thoracoscope is introduced first if two instruments are used and a site for introduction of the cauterizing instrument selected by thoracoscopic examination The area selected is anesthetized and the trocar and cannula introduced under thoracoscopic view The trocar is withdrawn and the cauterizing instrument introduced through the cannula The thoracoscope is usually introduced posteriorly an interspace below the elevated scapula If only one instrument is used it is usually introduced in the third or fourth interspace along the anterior axillary line

Thorough thoracoscopic examination precedes and determines whether or not cauterization is indicated and final results will depend largely upon the experience and judgment exercised by the surgeon in the thoracoscopic selection of adhesions for cauterization Those adhesions are selected for severing which are interfering with a satisfactory collapse of the diseased area It is unwise however to leave small adhesions uncut after severing the larger adhesions as the former may tear and give rise to a superimposed pneumothorax It is preferable therefore to cut the smaller adhesions first if cauterization is decided upon All sides of the adhesions should be visible before cauterization is attempted If this is not possible and partial cauterization of large band or curtain-shaped adhesions is contemplated the exact location of the lung and vascular structures in relation to the adhesion is a prerequisite The use of thoracoscopy in evaluating the extent of parenchymal disease or as an aid in diagnosis of pulmonary disease is I believe now of very little value and should be abandoned in favor of exploratory thoracotomy

Adhesions will generally not be difficult to locate however the size of the structure varies with *the distance from the thoracoscope The transition* between lung and adhesion is often indistinct in the larger band fold and funnel type of adhesions The blood supply of the adhesions is chiefly from the chest wall and coagulation of the adhesion is essential in an effort to prevent bleeding Usually it is a matter of slowly coagulating a surface of the adhesion severing a small portion by cauterization and again applying the coagulation current and cauterizing This process is repeated until the adhesion is partially or completely severed The pres-

ence of recently developed pleural fluid, associated with fever, makes the severing of adhesions undesirable and thoracoscopy would, therefore, not be indicated

The immediate operative dangers are bleeding due to severing vessels within the adhesion or injury to the large vascular structure such as the subclavian artery Damage to the lung with resultant bronchopleural fistula is a serious hazard [6,14 17–19] In the severing of large adhesions, ½ cm or greater in diameter, the pulmonary stump, if too short, may undergo necrosis during the early postoperative period and produce serious conse-



FIG. 22 —Closed intrapleural pneumonolysis *A* 1935 Extensive disease, left *B* 1936 Artificial pneumothorax, left Adhesions interfering with satisfactory collapse of cavity *C* 1936 One week after severing adhesions, left, by closed intrapleural pneumonolysis *D* 1952 Sixteen years later Patient is well and has been a police officer for 13 years

quences of fistula and empyema The late complications include empyema and obliterative pleuritis the former is of serious consequence while the latter may result in the loss of the pneumothorax space and nullify the objectives of the operation

The purpose of closed intrapleural pneumonolysis is to convert an unsatisfactory pneumothorax to a satisfactory one *i e*, cutting of offending adhesions This has been possible in our experience in 75 to 80 per cent of properly selected cases (Fig 22)

The almost complete loss of the need for this operation due to the marked decline 80 per cent or more in the frequency of applying artificial pneumothorax therapy results in a decrease in the expertness with which it is performed or at least fewer surgeons will have an appreciable experience It is an operation capable of offering considerable aid to certain patients undergoing artificial pneumothorax therapy [3] It is also fraught with considerable danger Unless the surgeon has frequent experience in its use it is recommended that some other method of management of the unsuccessful pneumothorax be employed Generally this means the abandonment of the pneumothorax and recommendation of other collapse therapy measures or extirpative surgery

Open Intrapleural Pneumonolysis The severing of intrapleural adhesions which are interfering with a satisfactory artificial pneumothorax may be accomplished by opening the thorax and cutting the adhesions under direct vision It has the appeal of a clean-cut surgical procedure [4] However it did not gain the popularity of closed intrapleural pneumonolysis and since the advent of chemotherapy has been seldom advised Since 1947 we have carried out the procedure only twice If it is accomplished it is recommended that a rib be resected as the closure of the chest utilizing the periosteal bed of the resected rib provides a better closure permitting early pneumothorax refills of air

Paralysis of the Hemidiaphragm. Therapeutic paralysis of the hemidiaphram in the treatment of pulmonary tuberculosis may be accomplished by three methods First phrenemphraxis *i e* crushing a section 1 cm of the main branch of the phrenic nerve in the neck with division of its accessory branches second phrenic exeresis, *i.e* the avulsion of at least 10 cm of the nerve through an incision in the neck third crushing the nerve as it lies on the pericardium at the time the chest is open in the performance of extirpative surgical procedures The first two were widely used in the prechemotherapy era Phrenic exeresis gave way to phrenemphraxis as the preferable procedure after about 1933 [9,10] With the decreasing use of collapse therapy measures both temporary and permanent hemidiaphragmatic paralysis has rapidly decreased in the frequency of their use The practice of crushing the phrenic nerve at the time of extirpative procedures has not in our experience been frequently employed Following the removal of a tuberculous lower lobe we occasionally crush the phrenic nerve with a hemostat for a distance of ½ cm along its course on the pericardium This is another example of an operative procedure extensively used in the collapse therapy era which is rapidly disappearing Approximately 2300 operations upon the phrenic nerve were performed for pulmonary tuberculosis at Fitzsimons Army Hospital during the period

1926–1946.[11,21] Since 1950 only 98 patients have been treated by hemidiaphragmatic paralysis alone or in combination with other collapse therapy and extirpative procedures.

The operation of crushing the phrenic nerve in the neck becomes relatively simple if the surgeon performs it with considerable frequency. However, if the operation is performed infrequently, the surgeon will do well to thoroughly review the anatomy of this area. An incision longer than that employed when these operations were frequently performed is advised for those who are not already thoroughly familiar with the operation. Local infiltration of procaine solution, 1 per cent, anesthesia is satisfactory. The incision is placed 1 inch above the clavicle and extends 2 to 3 cm. medially and laterally from the lateral border of the sternocleidomastoid muscle. The skin and platysma muscle are incised, and the sternocleidomastoid muscle retracted medially exposing the pad of fat over the anterior scalenus muscle. By digital palpation the latter muscle is felt and often the phrenic nerve on its anterior surface may be felt. The fat pad is separated by blunt dissection and the anterior scalenus muscle identified. Adequate exposure obtained by thin-bladed retractors, 4 to 5 cm. in depth, is essential. The phrenic nerve should be visualized on the anterior surface of the muscle. Its course is from above, across the lateral to the medial side of the muscle. After identifying the nerve it is isolated, injected with 1 per cent procaine solution, and by means of a forceps, crushed for a distance of about 1 cm. A careful search is made for accessory branches which are present in about three-fourths of adults. The accessory nerve is usually located as it emerges from the fifth root of the brachial plexus and followed as it courses along the lateral border of the anterior scalenus muscle. Any of the large vascular structures in the neck, especially the internal jugular vein, may be injured if the anatomical orientation is not accurate, also the cervical sympathetic chain and brachial plexus are easily damaged.

Hemidiaphragmatic paralysis is very unpredictable in its benefits. In general, and when used alone, lower lobe lesions derive the most benefit from this procedure.

Extrapleural Pneumothorax. A wide variety of substances have been employed as extrapleural filling material to collapse, relax, or compress the lung as an aid to the healing of pulmonary tuberculosis. These substances have included paraffin, fat, muscle, several plastic materials, oil, and air. The latter has been used for a considerable period of time, but it reached its widest use in the period of 1937 to about 1943.[4,15] It has since gradually decreased as a favorable procedure.[8] We have employed the procedure only once since 1947.

Extrapleural pneumothorax is accomplished by the surgical removal posterolaterally of a 6 to 10 cm. segment of the third or fourth rib. The extrapleural separation of the lung from the chest wall is accomplished by meticulous blunt dissection until the lung is separated from the chest wall, creating a space of varying size extending apically, posteriorly, laterally, and medially downward to the level of the fifth to seventh rib posteriorly. The wound is sutured by snug closure of the posterior bed of the periosteum of the resected rib and layer closure of the chest wall incision. The pres-

sure within the extrapleural space is measured by an ordinary pneumothorax apparatus a reading of 0 to plus 6 is desirable The space is maintained by refills of air varying in amount usually 75 to 250 cc. at intervals of from two to four weeks after the first month The air refills during this period are usually accomplished at three- to four-day intervals. The pressure variations generally change rather markedly with relatively small quantities of air as compared to intrapleural pneumothorax A change from minus 5 to plus 12 with about 75 cc of air is commonly noted The space and the compression of the lung is desirably maintained for periods of several months or longer

This procedure was advocated principally as a means of collapse therapy for those patients who were not satisfactory surgical risks for thoracoplasty applicable especially in older patients, *i.e* over fifty years of age with far-advanced plumonary tuberculosis. In general the initial success or appeal of this procedure gradually declined because of ancillary surgical aids *e g* improved anesthesia methods and the greater use of whole blood transfusion which extended the applicability of thoracoplasty The complications incident to its use also became increasingly frequent as the procedure was applied to the poor surgical risk patient It is in the group of patients most needful of such an operation that the adherence of the lung to the chest wall is most marked and difficult to separate the result being that the cavity is often perforated the space obtained is small re-adhesion more common the maintenance of air refills more difficult increased incidence of loss of the space fluid production and empyema These have led to the abandonment of the procedure in several clinics. Churchill emphasized the shortcomings of this procedure [7] In a few clinics and in the hands of its strong advocates excellent results are reported [8]

Extrapleural Plombage The recent appeal of this procedure is based on less irritating substances being made available namely the plastic materials Lucite methyl methacrylate was popular for a few years following the report of Wilson and Baker [27] However the poor sputum conversion rate and frequent complications along with the splendid results obtained from extirpative surgery have lead to the abandonment of lucite plombage in most clinics.[28, 29] We treated 11 patients with lucite plombage during 1948 but have since abandoned the procedure We have had no experience with other plastic materials. I prefer the five-rib thoracoplasty as a space closing procedure in lobectomy or pneumonectomy The subcostal extraperiosteal plombage is a preferable method

The substitution of extrapleural filling with air or plastic materials for thoracoplasty has the appealing plan of not removing several ribs and does not produce thoracic deformity This feature may lead to a compromise with what many believe to be the preferable method of producing collapse therapy *i.e* thoracoplasty I adhere to this belief and have not offered extrapleural methods as a substitute for thoracoplasty either as a primary method of surgical collapse or as a space-closing procedure associated with extirpative surgery A major disadvantage of plastics and other substances except air is that they obscure the lung structure to roentgenographic view and one has to rely entirely on clinical manifestations to ascertain

the trend of the disease, this loss of roentgenographic aid is a serious consideration

The operative procedure is performed in essentially the same manner as is extrapleural pneumothorax, except that the space created is filled with the plombage material rather than air

Summary. The collapse therapy of pulmonary tuberculosis has contributed greatly to the surgical advances in the management of this disease Its objective is to provide rest for the diseased lung, thereby aiding in the healing of tuberculosis It has been characterized by the introduction of several different methods, few of which have stood the test of time and experience Extrapleural thoracoplasty has been the single, most effective surgical method of collapse therapy The changing trend in the use of collapse therapy procedures is depicted in Table 3

Table 3. The Changing Trend in the Use of Collapse Therapy Procedures. Fitzsimons Army Hospital

	No of Times Employed		
Procedure	*1926–1946*	*1947–1952*	*1952*
Apicolysis, with paraffin filling	26	0	0
Cavernostomy	21	3	0
Decortication	10	55	5
Phrenic Nerve Operations			
Phrenectomy	20	0	0
Phrenemphraxis	1627	302	14
Phrenicoexeresis	694	0	0
Scalenectomy and phrenicoexeresis	11	0	0
Pneumonolysis, closed intrapleural	349	92	0
Thoracoplasty	1295	1285	113
Revision of	38	5	0
Total of all Collapse Therapy Procedures	4432	2382	132

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Chapter

4

Extirpative Surgical Therapy

Factors Determining Amount of Lung to Be Removed. *General* The amount of lung to be removed in the surgical treatment of pulmonary tuberculosis depends upon the balance of two aims, eradication of active disease and conservation of normal lung tissue Such a balance is a compromise in that tuberculosis is a generalized disease, and except in the infrequent strictly circumscribed lesions devoid of adjacent or distant involvement, the lungs in active pulmonary tuberculosis manifest multiple areas of involvement The conservation of what is considered normal lung tissue is generally something intermediate, as there is seldom strict demaraction from the normal zone The best compromise procedure is that which almost accomplishes the extirpation of disease and still conserves a maximum of normal lung tissue

Condition of the Less Involved Lung Both lungs are usually involved in active pulmonary tuberculosis even though the roentgenographic appearance of the less involved lung is normal Serial roentgenographic studies are the most effective means of ascertaining the extent of the contralateral lung involvement In the presence of active bilateral disease the less involved lung should be under adequate therapeutic control before extirpative surgery is performed on the more involved side The present chemotherapeutic agents are effective measures of such control, and collapse therapy measures are rapidly becoming unnecessary on the less involved side From 1947 to 1952 only 11 patients had artificial pneumothorax therapy on the less involved side at the time of extirpative surgery.

Extent, Nature, and Location of Disease Process It is mandatory that careful study of serial chest roentgenograms be made, preferably from the onset or date of disease detection, and at frequent intervals during the course of the disease prior to extirpative surgery Such a study should be the combined efforts of the roentgenologist, the phthisiologist, and the thoracic surgeon It is often essential to include in the roentgenographic study projections other than the usual postero-anterior, especially the apical which bring into clearer view the area above the second rib level anteriorly The lateral projection is also a valuable aid in ascertaining whether the cavity or lesions are in the upper or lower lobe, especially when the portion of the lung involved is located posteriorly in the region of the fourth or fifth rib

When the disease process, as evidenced roentgenographically, is limited to one lobe or a portion of one lobe, it is recommended that only the lobe or the appropriate portion of the lobe be removed However, the exper-

ienced thoracic surgeon refrains from a preoperative decision as to the amount of lung which he will remove. It is often observed at operation that the preoperative appraisal minimized the extent of the disease or occasionally exaggerated its boundaries. Rarely certain operative technical problems may require sacrifice of more lung than desired or the relinquishing of more involved lung than intended. The unfavorable condition of the patient during the course of the operation may also alter previously made plans.

The location of a lesion or lesions close to the hilus may necessitate a lobectomy, whereas if such lesions are located more peripherally, wedge excision or segmental resection would suffice.

Technical Considerations. The experienced surgeon will rarely have to alter the execution of a planned pulmonary lobectomy because of technical problems. Lobectomy, pneumonectomy, and segmental pulmonary resection are time-consuming operations requiring meticulous attention to details. With wide exposure of the operative field, full utilization of expertly administered anesthesia, and whole blood replacement therapy, hastening of the operation is unnecessary and dangerous. The anomalies of the pulmonary hilus are few, yet accurate knowledge of its anatomy is a requisite.[1–4, 6, 8–10, 13, 15–18] Injury to blood vessels, larger than those supplying the area which it is planned to remove, may require the removal of larger portions of the lung than contemplated. A pneumonectomy may become necessary because of injury to the main pulmonary artery when a lobectomy was all that was at first contemplated. *There is no substitute for care and strict attention to detailed dissection of the pulmonary hilus.* Rarely a pneumonectomy rather than a contemplated lobectomy may be necessitated due to injury of the main stem bronchus. Avoiding these accidents is far easier than their management after injury. Segmental resection requires the same meticulous dissection of the respective blood vessels and bronchus as does lobectomy. The complete mobilization of the lung, through a widely exposed operative field prior to isolation of the hilar structures, and avoiding haste are the secrets of preventing accidents at the time of operation.

Adhesions. Extensive adhesions obliterating the pleural space are frequently encountered in pulmonary tuberculosis. They are more prevalent in instances wherein pleural effusion and empyema exist or previous thoracic surgical procedures have been performed. The adherence of the lung to the pericardium and mediastinum are equally frequent. The management of such adhesions is a test of the surgeon's patience and ingenuity. Careful blunt digital dissection and the aid of small sponges attached to a long forceps, with observation by adequate lighting, is the best means of accomplishing separation of such adhesions. The entire lung should be mobilized prior to the dissection of the hilar structures, including separation of the lung from the diaphragm, as a mobilized lung permits control of the hilar structures should an emergency arise. In several instances in our experience a cavitary lesion was so densely adherent to the chest wall that the cavity was opened during the attempted separation. Due to the benefits of streptomycin protection there have been no serious complications attributable to this at times unavoidable

accident The cavitary contents should be immediately evacuated Dense bands of adhesions, especially in the apex of the thoracic cavity and near the diaphragm, should be ligated by transfixing sutures Small tears in the lung which may occur in the separation of adhesions, though undesirable, are seldom of major concern

Interlobar Fissure —Frequently the peripheral surface of the main interlobar fissure may be obliterated by adhesions which, when separated, expose a relatively free interlobar space The fissure between the right upper and middle lobes is seldom complete, probably only in 15 per cent of adults. It should be completed by transecting the lung between clamps The severed portion of the lung tissue which remains should be sutured before dissecting the hilus structures, if they have not been isolated It is seldom indeed that the obliteration of the interlobar fissure necessitates an extensive alteration in the planned or indicated operative procedure Pneumonectomy is rarely advised as a substitute for lobectomy because of obliteration of the interlobar fissure A seven-rib thoracoplasty is, in the absence of lobar bronchial stenosis, often preferable to pneumonectomy under such conditions

Endobronchial Disease The presence of healed stenotic endobronchial disease is best managed, in our experience, by lobectomy or pneumonectomy, depending on the site of involvement The excision of the stenotic area and suture of the bronchus, or the application of suitable grafts, has been advocated and accomplished with marked success by Gebauer [7] Ulcerative lesions visible bronchoscopically rarely warrant operation, as chemotherapy is effective in bringing about their resolution or at least aids in producing contraction and healing after which surgery may be indicated

Lymph Node Involvement of the Hilus The lymphoid tissue of the pulmonary hilus is often involved in the scarring and healing of the tuberculous process and becomes densely adherent to the vascular and bronchial structures When this occurs the dissection of the structures of the hilus is made more difficult, increasing the danger of injury to the bronchus and blood vessels In my personal experience lobectomy has been abandoned and thoracoplasty substituted because of densely matted hilar lymph nodes on only two occasions since 1947 We have not hesitated to cut across lymph nodes of the hilus or to remove them, realizing that they may be involved in the tuberculous process Enlarged hilar or mediastinal lymph nodes, which have been destroyed except for a firm fibrous capsule and which contain caseous material, are seldom suitable for removal because of their adherence to large vascular structures These lesions are managed by excising a large portion of the capsule, evacuating its caseous contents, and leaving the wall of the capsule attached to the vessels

Residual Foci The residual focus or foci which remain in the lung after maximum resolution from chemotherapy are being regularly removed surgically [5, 11] We have seldom considered it feasible to remove multiple foci from different parts of the lungs The small foci may appear to represent healed areas which a few years ago would have been accepted as a satisfying result after a long period of rest treatment, or as the residuals of a disease which had presented few symptoms These foci are not, how-

ever as innocent as often considered and their surgical excision has generally revealed lesions containing caseous material from which tubercle bacilli are identified The inability to grow these microorganisms in culture media or to produce tuberculosis in experimental animals does not at the present time prove that such organisms are not dangerous to the human host

Lobectomy The technical aspects of pulmonary lobectomy focus upon the identification isolation and individual ligation of the artery vein and bronchus supplying the lobe[2] The maneuvers to accomplish this are not difficult but require painstaking attention to details and are time-consuming The competent surgeon who has accurate knowledge of the anatomy of the pulmonary hilus will regularly require three to four hours in the performance of lobectomy In general its surgical execution for pulmonary tuberculosis requires neither more or less time than lobectomy for other causes Each of the five pulmonary lobes require but slight variations in surgical management for their removal (Figs. 23 24 and 25) In pulmonary tuberculosis the adherence of the parietal and visceral pleura is very common and the most frequent site is apically and posteriorly This is also the most common site for cavitation to occur

Two practical principles are significant in freeing the lung from the chest wall and in the performance of lobectomy first wide exposure of the operative field second the avoidance of haste The subperiosteal removal of an appropriate rib from the transverse process to the costochondral junction is the preferable first step toward attaining wide exposure An intercostal incision without rib removal is preferred by some if thoracoplasty is not contemplated Following rib removal an estimate of the adherence of the lung is in part possible If the parietal pleura is transparent and the lung is seen to move freely with respiration an appreciable portion of the lung may be assumed to be free of the chest wall However rather dense adhesions may be and often are present apically and posteriorly After the parietal pleura is opened inspection and palpation of the lung determines the presence and location of adhesions If the pleurae are thickened and the lung cannot be visualized considerable care is required in incising the parietal pleura to avoid injury of the lung As the pleura is incised its cut edges are elevated and by gentle blunt dissection the lung is separated from the chest wall The most difficult areas encountered in this separation are usually the apical posterior diaphragmatic and mediastinal These conditions are greatly increased in instances wherein a thoracoplasty has been performed several months previously A first stage three-rib thoracoplasty does not enhance technical problems The practice which I have found most helpful in freeing the lung employs meticulousness adequate light and patience

The entire lung is freed from any adherence to the chest wall pericardium and diaphragm by careful dissection Unless the adhesions are transparent ligation with a transfixing suture is desirable Two principles are satisfied by freeing the entire lung first it is technically easy to secure the main pulmonary artery and the superior and inferior pulmonary vein if uncontrolled bleeding from the lobar vessels should occur second the remaining freed lung will expand more uniformly to fill the hemithorax

after the removal of the lobe The lobe to be removed is separated from the adjacent lobe or lobes. All dissection is directed toward making the pulmonary hilus clearly visible and its structures easily identifiable and amenable to ligation Preferably all of this is accomplished before ligating the individual structures in the hilus

There is divergence of opinion as to the order in which these structures should be ligated, and many advise dealing with the bronchus first In my experience the competent anesthetist is able to aspirate the bronchial secretions, and postoperative spread, although always distressing, has fortunately seldom occurred and has not been considered to have been affected by whether or not the bronchus had been ligated first Furthermore, it seems ill-advised to immediately seek out the bronchus and ligate it before the more available vascular structures of the hilus are identified and isolated The use of chemotherapy has so markedly reduced the quantity of sputum produced by tuberculous patients that seldom do they have more than a few cubic centimeters of sputum in twenty-four hours We have not employed the face down position in thoracic surgery[13] The incision for thoracotomy is the standard posterolateral approach

The pulmonary artery is identified and its branches to the lobe to be removed are isolated The pulmonary vein to the lobe is also identified and its branches isolated The bronchus is identified and its isolation generally follows the severance of the blood vessels, especially for the upper lobe Ordinarily the arterial supply is dealt with first, the branches being triply ligated and a transfixing suture placed both on the proximal and distal ends, plus a simple ligature on the proximal end The transfixing suture is employed on the distal end simply to prevent the ligature from coming off with the resultant annoying bleeding from the lung The vessel is cut between the two distal sutures Patience and meticulous dissection are required in order to provide an adequate stump of the severed vessel If this cannot be secured, lobectomy should not be attempted Pneumonectomy may be feasible, or the surgical effort discontinued and thoracoplasty or other methods of management decided upon at a later date Occasionally in upper lobectomy a branch of the superior pulmonary vein is initially ligated to better expose the branches of the pulmonary artery to the upper lobe On the left, the arterial branches number four to seven and each is dealt with in the same manner, while on the right there are usually only about half as many

The pulmonary vein to the lobe to be removed is usually dealt with next, leaving the bronchus until last, especially in upper lobectomy

In performing lower lobectomy the vein is often dealt with before the bronchus has been divided and its proximal end sutured The pulmonary vein from the lower lobe is identified by elevating the lobe, freeing it from the diaphragm and pericardium, and observing the pulmonary ligament A lymph node is present in the upper portion of the ligament adjacent to the vein and aids in its location The pulmonary ligament is divided and its contained blood vessels ligated The pulmonary vein is identified, isolated, triply ligated, and divided, leaving one suture on the lung stump If the main division of the inferior pulmonary vein is not clearly isolated, its

branches are dissected and dealt with in the same manner as the arterial branches are managed

After the vascular structures are disposed of the bronchus is freed of adjacent tissue and the bronchial artery branches are identified doubly ligated and severed between the ligatures. Clamps are seldom placed on the bronchus. A heavy silk ligature is placed through the lobe bronchus in its distal portion but usually not tied until the bronchus is transected The bronchus is cut across at a level which permits an adequate stump for suturing A stump in excess of ½ centimeter is undesirable The proximal

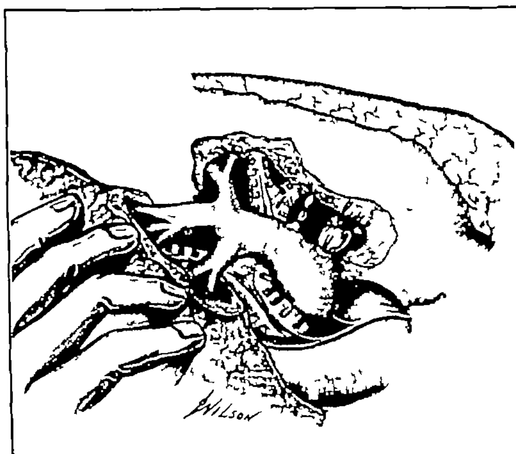


FIG 23 —Left upper lobectomy Branches of the pulmonary artery are being ligated branches to lingula isolated.

end of the lobe bronchus is closed with simple interrupted 0000 silk suture Atraumatic 00 chromic catgut suture has been used with equally good results. The lobe is then removed

The lower lobe of either side is removed in similar manner The pulmonary ligament is severed and the arterial structures are dealt with first Usually the arterial branch to the superior division is dealt with separately as its origin from the main pulmonary artery so closely approximates the origin of the right middle lobe arterial supply or the lingula branch on the left as to endanger these structures. The remainder of the

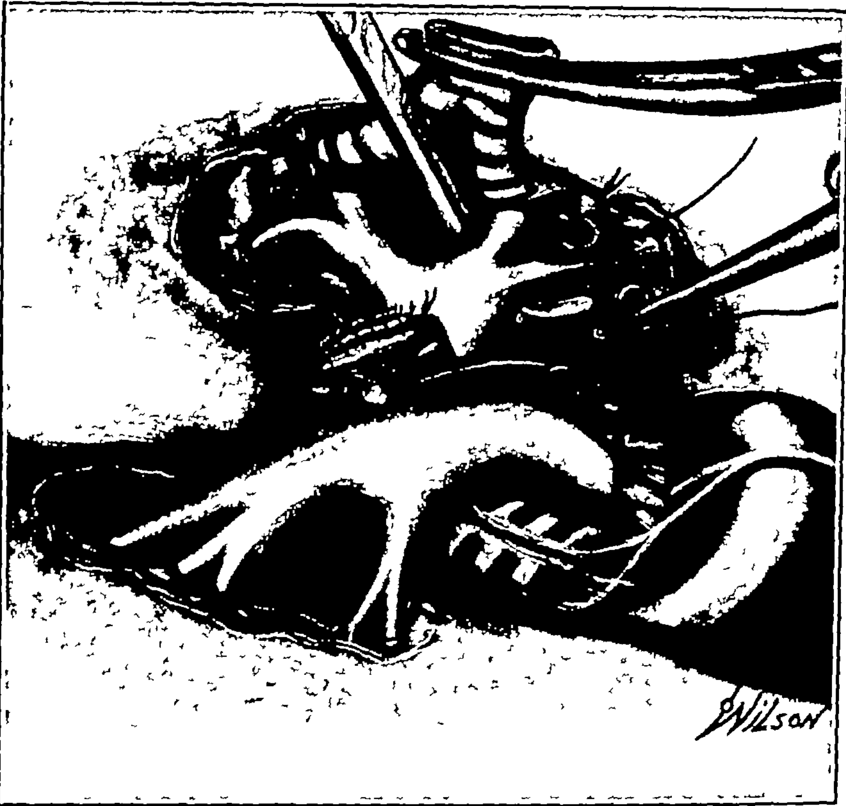


FIG 24 —Left upper lobectomy Pulmonary artery branches have been ligated, bronchus cut, and proximal end sutured Superior pulmonary vein ready for ligation The vessels are usually ligated and cut before the bronchus is transected



FIG 25 —Left upper lobectomy Pulmonary vein ready for ligation, showing anterior and medial surface of lobe Branches of pulmonary artery have already been ligated

arterial supply to the lower lobe may be ligated proximally to its branch divisions or the branches themselves may be individually ligated Triple ligation is employed a transfixing suture being placed distally and both a transfixing suture and simple ligature proximally The pulmonary vein from the lower lobe is identified and treated as noted in the preceding paragraph The bronchus is treated as described for the upper lobe The superior lobe bronchus may be dealt with separately before the rest of the bronchus is divided

Careful ligation of any bleeding vessels and the suturing of air leaks is accomplished Two 45 F right angle catheters are placed intrapleurally making their exit one in the posterior axillary line in the eighth or ninth intercostal space and the other in the anterior axillary line in the third or fourth intercostal space The catheters are connected with under water drainage bottles The wound is closed in layers with interrupted silk suture A small dressing is applied The anesthetist accompanies the patient to the ward remaining until the patient is awake The endotracheal anesthesia tube is usually removed in the operating room Bronchoscopy immediately after lobectomy is rarely indicated

Pneumonectomy Pneumonectomy in the treatment of pulmonary tuberculosis has been employed in only 22 of the patients 5 per cent treated by extirpative surgery 1947–1952 a much lower percentage than generally reported [12] This is probably due to three factors first the patients we have been privileged to treat have represented in general the young soldier whose disease has been detected early second the chemotherapy regimen and bed rest has been accomplished in most all instances in this hospital and third a moderate amount of visible and palpable tuberculous disease in the lower lobe and extensive disease in the upper lobe does not indicate pneumonectomy an upper lobectomy and a five-rib thoracoplasty is preferable

Pneumonectomy performed in the treatment of pulmonary tuberculosis presents the same technical problems as encountered in its performance in other non-neoplastic disease (Figs 26 and 27) The principles followed are complete mobilization of the lung severing the pulmonary ligament and individual isolation of the vascular structures and main stem bronchus of the pulmonary hilus before ligating these structures After the hilar structures are identified and isolated I have generally proceeded by first ligating and severing the pulmonary artery Double ligation of the proximal end of this vessel one of which is a transfixing suture is regularly practiced The superior pulmonary vein is next ligated and treated in a similar manner the bronchus usually being the next structure to be severed and its proximal end closed by interrupted 0000 silk sutures We have seldom used more than a single row of interrupted sutures No effort has been made to remove rings or cartilages or to cut one edge of the bronchus appreciably longer than the other [11] Simplicity and meticulous suturing have been the principles employed in the treatment of the bronchus The inferior pulmonary vein is the final structure ligated and in the same manner as the pulmonary artery Silk sutures No 0 or 00 are employed in ligating these large vascular structures Intrapericardial dissection of the structures of the pulmonary hilus is rarely



FIG 26 —Left lung and pulmonary hilus Anterior and mediastinal surfaces

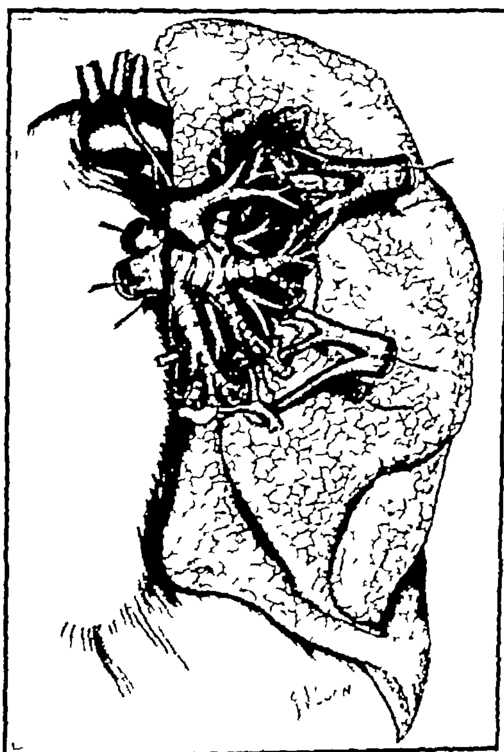


FIG 27 —Left lung and pulmonary hilus Anterior and mediastinal surface The pulmonary vein has been severed

necessary The lymph nodes in the hilus are often firmly matted to the vascular and bronchial structures making dissection difficult The operations employed in extirpative surgery except wedge excision do not lend themselves to speed in their performance The tuberculous patient undergoing these procedures is able to withstand a long operation properly supported by excellent anesthesia management and whole blood replacement Haste in the performance of the operation is not only undesirable but often dangerous

Segmental Resection. The segmental resection of tuberculous lung tissue is being increasingly employed effectively in the treatment of pulmonary tuberculosis[5, 12] *The anatomical basis for segmental resection is* the structure of the bronchopulmonary segment described by Boyden Scannell and others.[4, 6, 8, 10, 13, 14–17] The basis for its application in the surgical therapy of pulmonary tuberculosis is that tuberculosis is most often located in the apical and posterior segments of the upper lobe of the lungs. The chemotherapeutic agents have been a great boon in increasing the tendency of tuberculous lesions to become localized within the lung thus enhancing the use of this surgical procedure[11] For example in 1947 1948 and 1949 we employed segmental resection in only 6 patients undergoing extirpative surgical therapy while during the first six months of 1953 51 patients were treated by segmental resection

The surgical technique employed has been based on the same surgical principles as lobectomy or pneumonectomy namely the meticulous dissection of individual structures of the pulmonary hilus (Fig 28) Each structure is prepared and all are made ready for ligation before any one is ligated For segmental resection this involves the principle of exposure of the respective bronchus and arterial and venous branches before these structures are individually severed The transection of the lung tissue of the segment or segments removed is in my opinion preferably managed by the clamp and suture method using a double row of 00 atraumatic catgut suture. In the application of the clamps care should be exercised to include a small rather than a large area in the clamp The interrupted suture method to close the transected lung tissue is preferred by many authors Unless all vessels on the cut lung surface are separately ligated and the interrupted sutures used simply to approximate the cut edges of lung a double row of continuous suture of catgut is a more efficient hemostatic suture We have observed four large intrapulmonary hematomas develop following segmental resection when interrupted sutures alone were used None has been noted in segmental resections where the clamp and continuous suture of the transected lung tissue was accomplished

Wedge Excision. The removal of lung tissue by wedge excision is frequently selected as a method of surgical therapy for pulmonary tuberculosis. The tuberculoma lesions and small peripherally located residual foci comprise the main indications for wedge excision During 1947 to June 3 1953 113 patients have undergone wedge excision of tuberculous lesions

The surgical technique employed in wedge excision is simple and positive After exposure of the lung by rib resection or intercostal incision the lesion or lesions to be removed by wedge excision are usually subpleural

peripheral, and of firm consistency and easily visualized and palpated Their removal is accomplished in the following manner the lung tissue to be removed is grasped by the surgeon's thumb and index finger Clamps, preferably the Kocher type, are applied in a manner so that a "V" shaped area of the peripherally involved lung is contained between the clamps The tissue to be removed is transected with scissors A 00 catgut suture on an atraumatic needle is used to suture the cut area of the lung A double row of continuous suturing is employed The first row is placed below the clamp, the excess lung tissue above the clamp is excised, and the clamp is removed The second layer is placed so as to bring the pleural surfaces together and invert the cut edge of the lung The same method of suturing is carried out on the opposite cut section of the lung No attempt is made to bring these two sutured lung surfaces together, as it is believed that the healing reexpansion of the lung is better accomplished without approximating the edges of the "V" excision When the lesion to be removed requires the dissection of the corresponding bronchus and vascular supply and does not necessitate lobectomy, segmental resection is preferable

Bilateral Extirpative Surgical Therapy. Bilateral extirpative surgery is rarely indicated, and except for a few bilateral lesions as tuberculomas or small residual foci, we have not recommended such procedures The method of application is the same as for unilateral procedures

Summary. Extirpative surgical therapy in pulmonary tuberculosis has been made feasible for wide application largely through the use of chemotherapy The operative procedures being used with steadily increasing frequency are those which are directed toward conserving normal lung or less involved lung and extirpating the more diseased areas Lobectomy, segmental resection, and wedge excision are meeting this requirement Pneumonectomy is seldom indicated The surgical principles and details of their technical application are described

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Fig 28.—Segmental resection Vascular structures and bronchus have been isolated and divided

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Part III

Experience With Surgical Therapy in Pulmonary Tuberculosis

Chapter

5

General Considerations in Surgical Therapy

Incidence of Patients Treated Surgically The recent rapid increase in the incidence of patients treated surgically indicates the improved results obtained One out of every 4 patients suffering from pulmonary tuberculosis presently being treated at Fitzsimons Army Hospital receives surgical therapy To predict the developments of even the immediate future would be unwise However with early detection of the disease immediate and prolonged chemotherapy and facilities for complete rehabilitation there seems to be every reason for extending the application of surgical therapy Excluding pneumonectomy our operative mortality for the surgical therapy of uncomplicated pulmonary tuberculosis since 1947 including all deaths within sixty days has been 1 8 per cent That this low operative risk may be still further decreased is an incentive to those advocating surgical therapy

A large factor in the utilization of surgical therapy is the experience of the recommending physician The tendency to evaluate therapy on the basis of a personal experience which may have led to his own recovery from tuberculosis or upon an intimate knowledge of an occasional case problem is often a dominant factor in the recommendations to his friends and patients A particular procedure may gain the physician s favor and the tendency to over recommend it and deprecate developments subsequent to his own experiences is not an unusual occurrence Further the enthusiasm of the hospital s staff or lack of zeal for surgical therapy is a predominant factor in its frequency of application This waxing and waning has been evidenced in our own hospital In 1930 the enthusiasm for surgical therapy was great and 89 patients were treated by extrapleural thoracoplasty while nine years later the staff did not share such enthusiasm and only 11 patients were treated by thoracoplasty This treatise will serve I hope to acquaint those physicians who do not devote a con

siderable part of their time to the clinical problems of tuberculosis with recent developments in the applicability of surgery. To those who are daily concerned with the therapy of pulmonary tuberculosis, my desire is to relate an experience which may be valuable to them in appraising their recommendations concerning surgical therapy. The true balance of the incidence of surgical therapy, under present conditions, must await a longer period for observing patients treated without surgery as compared to those receiving such therapy. In the meantime, its more frequent employment is recommended.

Anesthesia. *General.* The advances in anesthesiology have paralleled and often preceded those of thoracic surgery. It is certain that the improved techniques and methods of anesthesiology for the past thirty years have been paramount in broadening the scope of surgery in the treatment of pulmonary tuberculosis. I am indebted to Lieutenant Colonel John F. Kellogg, Medical Corps, U. S. Army, Chief of Anesthesiology, Fitzsimons Army Hospital, for most of what follows concerning anesthesiology in the surgery of pulmonary tuberculosis.

History. The route which has been traversed to reach the present excellence of anesthesiology in the surgery of pulmonary tuberculosis began in about 1794 when Person, in England, suggested the use of inhalation of ether in the treatment of phthisis. Endotracheal intubation as a method of administering an anesthetic agent was used in 1869 by Trendelenburg on a patient following a tracheostomy. Chloroform dropped on a flannel covered funnel connected to the endotracheal tube was the anesthetic agent. In 1878, Macewen, of Scotland, was probably the first to administer anesthesia through an oral endotracheal tube. Kirstein, 1895, suggested the introduction of the endotracheal tube under direct laryngoscopy. Elsberg and Jackson popularized this method in the United States during the first decade of this century. In 1910 McKesson produced an anesthetic apparatus capable of delivering gases at a predetermined pressure which made possible the use of the "reduced pressure chamber." The endotracheal tubes popularized by Flagg, Magill, Rowbotham and others are now in common use. The endotracheal method of administering anesthetic agents has been a major contribution to the surgery of pulmonary tuberculosis.[11, 13, 17, 18, 26, 29, 33]

The anesthetic agents have varied but ether has retained a high degree of preference by many of the authorities.[5, 13, 19, 23, 24, 26] Cyclopropane has become a favorite agent of many during the past two decades.[29] We have not employed it in our work, nor have we used ethylene or trichlorethylene. The use of spinal anesthesia in the surgery of pulmonary tuberculosis has been advised but here again we have had no experience.[7, 10, 34]

Pentothal Sodium, Local Procaine, and Inhalation Nitrous Oxide Anesthesia for Extrapleural Thoracoplasty. Pentothal sodium and local procaine, and inhalation nitrous oxide anesthesia was employed in 186 patients on whom 502 thoracoplasty operations were performed during the two-year period, 1947–1948.[18, 21, 27] The techniques used in this study were reviewed by Major W. L. Lumpkin and the author. The premedication was individualized but, in general, comprised a barbiturate, 0.1 gram the night before operation and the morning of operation, plus moderate doses of

morphine and scopolamine averaging 0.01 gram and 0.0004 gram respectively. Every effort was made to provide an atmosphere of quiet for the patient in the operating room. The initial intravenous injection of 3 to 5 cc. of pentothal sodium in a 2½ per cent solution was given rather rapidly and further injections of 2 to 5 cc. are repeated as indicated, waiting a reasonable time for effect after each injection. As the patient loses consciousness nitrous oxide oxygen inhalation mixture, 50 per cent nitrous oxide, is started and the flow of the gases maintained above 2000 cc. per minute. The injection of procaine 1 per cent is carried out by the surgeon with infiltration along the course of the skin and muscular incision. Two per cent procaine is used for anesthetising the intercostal nerves and periosteum. Very little pentothal is required following the intercostal nerve blocks and the patient is maintained in a light sleep with 1 to 2 cc. of pentothal every ten to fifteen minutes. As the rib resection begins assisted respiration is accomplished until the operation is complete. Blood transfusion is continuous during the operation and maintained until after the patient is returned to his ward.

Certain factual data were obtained in this study. Laryngospasm occurred in 1.3 per cent of the operations to a degree requiring the intravenous injection of 40 to 80 units of curare. Transient coughing was noted in 2 per cent of the operations and the method was inadequate to produce satisfactory anesthesia in 1.6 per cent of the operations. Ether was the agent selected in all instances when a change from pentothal was required. Seldom was the total of 2 grams of pentothal sodium exceeded. To change to ether 60 to 100 units of curare were administered intravenously, endotracheal intubation accomplished and ether gradually administered. Ninety-one per cent of these patients had far advanced disease, the remainder were moderately advanced. Streptomycin in varying doses, often large according to present standards, had been administered for varying periods of weeks or months. In 90.7 per cent of these patients more than one stage of thoracoplasty was accomplished. The patients collectively had an average of 2.7 operations per patient. The amount of procaine used averaged 91 cc. The average dose of pentothal sodium was 1.28 grams. Operative time averaged one hundred and five minutes.

The very early recovery of an effective cough mechanism is an important consideration in patients undergoing surgery for pulmonary tuberculosis and was a principal factor in this particular anesthesia technique. The patients react within three to five minutes after the nitrous oxide is discontinued and are generally able to cough effectively by the time return to the ward is accomplished. Effective coughing minimized spreads associated with surgical therapy. In this regard results were good: only 3 patients, 1.0 per cent, or in 0.6 per cent of the operative procedures was there early evidence suggestive of spread of the tuberculous disease. Two of the 3 patients had not been treated previously with streptomycin. In 1 patient a massive bronchogenic spread resulted in rapid progression of the disease and death. This method of anesthesia was not employed in those patients who produced large quantities, 75 cc. or more, of sputum.

The technique is not complicated, the results were considered satisfactory and the experience interesting. However, it did not seem to us

to offer advantages over our previous practice of employing the endotracheal method, and we have abandoned the use of pentothal sodium, local procaine, and nitrous oxide inhalation

Endotracheal Technique The techniques which we have employed with few modifications during the past several years are based principally upon the ether oxygen agents The day preceding the operation the anesthesiologist reviews the clinical record, appraising the patient's physical status An interview with the patient is conducted explaining in understandable terms what the patient may expect concerning the time the operation will begin, and the fact that, on awakening, he will receive oxygen therapy and intravenous fluids These are also emphasized by the surgeon and the patient is informed that intercostal drainage tubes will probably be inserted at the time of the operation The anesthesiologist carefully questions the patient regarding previous illnesses, operations, and allergic manifestations, especially to drugs and avoids their use With this information assembled, the anesthesia program for that patient is determined and the preoperative orders written In the absence of contra-indications, one of the short acting barbiturates, usually pentobarbital sodium (Nembutal), is prescribed for oral administration at bed time and repeated two hours before surgery The estimated dose of morphine or demerol and atropine is given hypodermatically one and one-half hours prior to the time scheduled for the induction of anesthesia This contact between the anesthesiologist and the patient does much to allay the latter's apprehension, which contributes to a smoother anesthesia and probably a better postoperative course

It is not uncommon to note that the tuberculous bedridden patient is very vulnerable to the hypotensive effects of morphine, dosages of even .008 or 005 grams may be followed by a drop of systolic blood pressure of 30 to 50 mm of mercury which responds poorly to the vasopressor drugs If this occurs prior to the commencement of operation, cancellation of the procedure is usually good judgment In reevaluating such a case problem for operation at a later date, opiates are usually withheld

The induction of anesthesia is preceded by an intravenous drip of 5 per cent glucose in distilled water or normal saline solution Occasionally a vein in the arm or lower leg, is exposed and used for intravenous administration A three-way stopcock is interposed in the intravenous circuit for the administration of pentothal sodium A test dose of pentothal is administered and if there are no untoward effects, and such effects are unusual, pentothal sodium, 2½ per cent solution, is administered slowly until the lid reflex is lost Oxygen in a concentration of 100 per cent is administered by face mask for two to three minutes, by the clock, assisting respirations as needed Additional pentothal is administered to a point approaching apnea, and at this time it is immediately followed by a calculated dose of a relaxant, such as Anectine or d-tubocurarine

The usual dose of curare in the young adult in good general condition has been one unit per pound of body weight Smaller dosage is advisable in debilitated and older persons All patients are weighed immediately preoperatively Oxygen, 100 per cent concentration, is administered for one or two minutes, then the pharynx and glottis are sprayed under direct

laryngoscopic vision with a 4 per cent cocaine. Oxygen is again briefly administered and the selected endotracheal tube inserted the size for adults varying from 34 to 40 F with a low pressure inflatable cuff The cuff is inflated ether administration started slowly and pentothal discarded Blood pressure and pulse determinations are made before induction after intubation and final positioning The patient is not taken from the adjoining anesthesia room into the operating room until his general condition appears stable.

Abrupt changes in the position of a patient who has had a prolonged general anesthetic are poorly tolerated The patient when moved is transferred directly to his bed in the operating suite thus avoiding further change on his arrival on the ward The continuance of blood and fluid replacement therapy is decided upon by consultation with the surgeon Oxygen therapy per nasal catheter is continued thirty to sixty minutes on return to the ward by which time the oxygen concentration in the tent will have reached a satisfactory concentration. Before the patient is released to the postoperative ward nurse, a final check must be made to recognize any residual effects of curare these include intercostal paralysis shallow diaphragmatic breathing and diminished or absent corneal reflexes Prostigmin or Tensilon will counteract any curare intoxication. Tensilon is preferable and is administered intravenously in 1 cc increments until the desired effect appears, but Tensilon itself has a transient effect lasting only ten to fifteen minutes At the conclusion of a properly managed anesthetic, few patients will require decurarization.

There are three special requirements which concern the anesthesiologist first is providing adequate oxygenation for the patient second is his role in guiding replacement therapy and third is constant attention directed toward the complete and frequent removal of fluid and secretions from the tracheobronchial tree.[22] Poorly understood reflexes related to the surgical manipulations of the pleura, phrenic nerve the vagus nerve and its plexus may introduce significant changes producing hypoxia bradycardia and even cardiac standstill The recognition of these possibilities and competence in the performance of the above three requirements of the anesthesiologist are the chief means of minimizing their dangers.

Periodic suction applied through a fairly large bore polyethylene catheter introduced through the endotracheal tube at frequent intervals and whenever the presence of secretions or fluid is suspected must be utilized The surgeon should be consulted before such suction aspiration is accomplished as he may be busily concerned with tedious dissection and coughing on the part of the patient would be undesirable with a few seconds notice he is usually able to temporarily defer his activities while the anesthesiologist removes the secretions Suction aspiration may often be combined with inflation of the collapsed portions of the lung on the operated side Suction should always precede inflation and it is desirable to accomplish the latter at about thirty minute intervals. Although aspiration of the tracheo-bronchial secretions and accumulated fluid is most important it is essential to avoid unnecessary repetitions as a rapid and significant decrease in arterial oxygen saturation may ensue and is poorly tolerated

As the operation is brought to a conclusion, two 45 F, right angle catheters are inserted intercostally in the intrapleural space in patients undergoing removal of lung tissue, except pneumonectomy, and are connected with a water-seal bottle The hemithorax is emptied of air by the anesthesiologist applying gentle positive pressure to the lungs As the wound is closed nitrous oxide and oxygen mixture in a 2 to 1 or a 3 to 1 concentration is administered and ether discontinued Through cleansing of the tracheobronchial tree is accomplished, the endotracheal tube removed, and oxygen per nasal catheter administered The cough reflex must be present and reaction from the anesthesia well progressed before the patient is returned to the recovery ward

The use of techniques which will deliver the anesthetic agent to the contralateral lung only, have occasionally been useful The blocking of the intercostal nerves prior to the closing of the wound with a long lasting agent is of questionable benefit

Complications All complications which may arise during the course of the operation are important to the anesthesiologist, and their management is closely associated with the conduct of the anesthesia One is of special concern to the anesthetist, namely, cardiac arrest [4,6 28] In retrospect, cardiac standstill has doubtless occurred many times without being recognized by the anesthesiologist When there is a real or suggested disappearance of the pulse and blood pressure, the surgeon must be immediately informed and asked to note the heart rate or vessel pulsations The anesthesiologist immediately ausculates the heart Time is, of course, of the essence Three to five minutes of inadequate cerebral oxygenation means death A timekeeper using a stop watch should be designated prior to the commencement of any operation and he should announce the passage of each thirty seconds No hesitancy is warranted in exposing the heart, if the operative procedure does not involve this maneuver The pericardium should be widely opened and the heart grasped by the hand and rhythmic compression, 60 to 80 per minute, carried out If a systolic blood pressure of 70 mm of mercury is not immediately evidenced, the thoracic aorta should be digitally compressed to divert oxygenated blood to the cerebral and coronary circulations The peripheral circulation at this juncture is not important. The endotracheal tube should be rapidly placed, if not already, *in situ* Oxygenation is the essential above all else If ventricular fibrillation is present the rhythm must be changed. Oxygenation and manual compression of the heart may accomplish a change Certain drugs may aid, especially procaine amide in a dosage of 100 mg per minute, intravenously, or procaine 1 per cent topically applied to the cardiac chambers or injected into the left ventricle If success is not rapidly achieved, the heart should be subjected to electric shock An alternating current of 1 5 amperes delivered by a suitable apparatus, for periods of one-half to one second is recommended An interval of fifteen to 20 seconds should be allowed for the heart to return to a sinus rhythm while manual rhythmic compression is continued [4] If the heart is in standstill, intracardiac injection of 1 to 1000 epinephrine may be beneficial In neither ventricular fibrillation nor cardiac standstill will it be possible to resuscitate the heart if oxygenation of the myocardium is not accom-

plished On the restoration of normal rhythm calcium chloride, 2 to 5 cc. of a 10 per cent solution may make the heart beat more effectively The use of atropine in the preoperative preparation and during the course of a prolonged operation is advisable as a preventive for cardiac arrest [22]

Pulmonary Function The anesthesiologist is very much concerned with the patient s pulmonary function. If the greater part of the respiratory function is being carried by the side being operated upon the condition becomes of even greater concern A resting minute ventilation of less than half the maximum breathing capacity should warrant serious consideration as to the feasibility of subjecting the patient to thoracoplasty or extirpative surgery for pulmonary tuberculosis. It is desired to point out that some patients will actually evidence an improvement of pulmonary function following the surgical removal of diseased lung tissue, especially if decortication of the remaining lung tissue is needed and accomplished (see Fig 43)

Care of Anesthesia Equipment After Surgery on Tuberculous Patients Anesthesia machines are thoroughly washed with green soap and water followed by alcohol The breathing tubes mask, bag casting and ether jar are placed in a solution of green soap and water and allowed to soak for an hour All other equipment such as endotracheal catheters airways suction catheters, and blades from the laryngoscopes, are first placed in a detergex water solution for an hour After having been soaked in green soap and water the following equipment is boiled for ten minutes (1) Rubber suction catheters (2) airways (3) mask and casting, and (4) syringes and needles The endotracheal catheter with cuff and the blade from the laryngoscope are then placed in a zephiran solution 1 1000 All endotracheal catheters for tuberculous cases are kept separate from the others

Other equipment such as the stethoscopes blood pressure apparatus and handles from the laryngoscopes are washed with green soap and water followed by alcohol Following this procedure they are exposed to the air for a few hours.

Surgical instruments are put to soak in a detergent After soaking thirty minutes or more, any remaining particles are removed with a brush They are then autoclaved before being taken from the room The unused linen glassware and anything else suitable for autoclaving are so treated The needles scissors and tubes of sutures are soaked in a separate pan of detergent and then thoroughly cleaned The walls of the rooms the lights standards basin stands tables and other furniture are washed with green soap solution followed by alcohol The floor is scrubbed with a strong solution of soap and cleanser Rooms are preferably reserved for the performance of surgery on patients having pulmonary tuberculosis

Summary Anesthesia for the surgery of pulmonary tuberculosis demands of the anesthesiologist the same careful and meticulous care as does anesthesia for other types of surgery plus many special considerations demanded by the disease itself This is true regardless of the method of approach but particularly when general anesthesia is the method of choice The best immediate and long range results will be seen when the

task is always assigned to the expert The novice must be constantly supervised during his association with this type of surgery.

Blood Loss and Blood Replacement. The estimation of blood loss in surgical operations is of primary importance in determining the amount of blood replacement needed In 1951, we reported a study representing our approach to the problem in thoracic surgery [9,14,25]

Blood volume was measured with the Evans blue dye (T-1824) method, and 191 patients undergoing thoracic surgical procedures were studied. In 120 operations on 94 patients, blood volume studies were made one to eight days before operation, 80 per cent within four days before operation and within twenty-four hours after operation Two weeks after operation, blood volume determinations were repeated on 33 of these patients Blood volume changes were studied in 82 patients suffering from pulmonary tuberculosis treated by extrapleural thoracoplasty The mean average blood volume changes, amount of blood transfused, and percentage change are tabulated in Tables 4 and 5

Table 4 Blood Volume Determined by Evans Blue Dye (T-1824)

(Forsee, J H *et al*, Arch Surg *65*, 88, 1952)

	Mean Averages		
	Normal Soldiers or Students	*Non-tuberculous Patients*	*Tuberculous Patients*
Number	87 0	20 0	116 0
Age (yr)	27 0	31 0	30 0
Weight (kg)	70 2	69 0	68 1
Blood Volume (cc /kg body wt)	79 1	77 6	75 8
Plasma Volume (cc /kg)	41 0	39 9	39 7

Table 5. Blood Volume Change Twenty-four Hours Following Thoracoplasty for Tuberculosis

(Forsee, J H *et al*, Arch Surg *65*, 88, 1952)

		Mean Averages		
Stage	*No of Patients*	*% Change in Blood Volume*	*Calculated Blood Loss, cc*	*Blood Transfusion, cc*
First	48	−10 9	2,061	1,521
Second	23	−12 1	1,716	1,065
Third	11	− 3 9	1,201	1,014

If the difference in the blood volume pre- and postoperatively, exclusive of the amount of blood administered by transfusion, indicates the total blood loss in these operations, out studies suggested a considerably greater loss than generally recorded It is significant that the studies being reported are based on values determined twenty-four hours after operation while other studies generally have been based on determinations made

shortly after operation.[1,20,34] During this twenty-four hour interval the extrafascial space created by thoracoplasty is often filled by blood and fluid; also blood in the pleural cavity cannot be considered part of the effective circulating blood volume and therefore is not measured by the blood volume determination. These factors and findings suggest that considerably more blood is needed for replacement than is generally employed. We do not believe, however, that blood volume studies as determined by the Evans blue dye reflect exactness in ascertaining the amount of actively circulating blood. In special studies in approximately 20 cases no correlation was found between the blood volume changes and variations in venous pressure, and between the blood volume changes and measurement of blood coagulation by the Lee White method.

Table 6. Blood Loss Determined by Dry Weighed Sponge Method Thoracoplasty for Tuberculosis

(Forsee, J. H., *et al.* Arch. Surg. *65*: 88, 1952)

	Mean Averages		
Stage	*No. of Patients*	*Blood Loss, cc.*	*Blood Transfusion, cc.*
First	34	973	1,308
Second	10	755	1,050
Third	4	771	875

Table 7. Comparison of Blood Volume Determination on Same Patients by Evans Blue Dye (T 1824)

(Forsee, J. H., *et al.* Arch. Surg. *65*: 88, 1952)

Before and 14 Days After Thoracoplasty in Tuberculosis

		Mean Averages					
		Blood Volume			*Plasma Volume*		
Stage	*Cases*	*Preop*	*Postop 14 Days*	*% Change*	*Preop*	*Postop 14 Days*	*% Change*
First	19	4,842	4,730	−2.3	2,554	2,539	−0.6
Second	3	4,932	4,479	−9.2	2,538	2,252	−11.3
Third	5	4,239	4,197	−0.97	2,268	2,201	−3.0

In another group of unselected patients studied, we found the calculated blood loss as determined by the Wangensteen dry weighted sponge method to be as given in Table 6.[3] Blood volume determinations were made two weeks after operation on 27 patients treated by thoracoplasty. The variations noted are recorded in Table 7. The group averaged a recovery of 97.7 per cent to the normal preoperative blood volume level in the first stage thoracoplasties, 90.8 per cent in the second stage, and 99.3 per cent in the third stage. These data, even though the number of patients studied is small, suggest, we believe, that the use of larger quantities of blood than that calculated as lost at the time of operation by the weighed

sponge method is desirable It is probably a significant factor in the early recovery after operation and in preparation for subsequent stages of operations

In a group of tuberculous patients treated by thoracoplasty the comparison of blood loss calculated by the weighed dry sponge method and blood volume (dye method) determination is recorded in Table 8 It should be remembered that the blood volume loss calculated from the dye method represents the changes twenty-four hours after operation, whereas the sponge method represents only operative loss, and the difference we believe emphasizes and justifies the giving of transfusions in excess of the estimated operative loss

Table 8. Comparison Between Blood Loss Determined by Weighed Sponge and Blood Volume (Dye) Method on the Same Patients. Thoracoplasty for Tuberculosis

(Forsee, J H *et al*, Arch Surg *65*, 88, 1952)

		Mean Average		
		Blood Loss		
Stage	*No of Patients*	*Blood Volume (Dye Method), cc*	*Weighed Sponge Method, cc*	*Blood Transfusion, cc*
First	12	1,832	971	1,333
Second	5	1,778	620	1,000
Third	4	1,045	647	875

Table 9. Blood Volume Change Determined by Evans Blue Dye (T-1824). Lobectomy for Tuberculosis

(Forsee, J H *et al*, Arch Surg *65*, 88, 1952)

	Mean Averages		
No Patients	*Blood Loss, cc*	*Blood Transfusion, cc*	*% Change*
20	2,494	1,900	−11 0

Blood volume changes in 20 patients with pulmonary tuberculosis treated by lobectomy are recorded in Table 9 A three- to five-rib thoracoplasty had preceded upper lobectomy A comparison with estimated blood loss as determined by the dry weighed sponge method is noted in Table 10

Decortication of the lung may be a relatively simple procedure with slight to moderate blood loss, or a very difficult one with marked blood loss In general, tuberculosis probably gives this procedure its severest test relative to blood loss The data referable to 6 unselected patients indicate an average blood loss of 2,217 cc as determined by blood volume studies

In our studies no reliable evidence was found to indicate that the red blood cell count hemoglobin determination or hematocrit values could be used to determine blood loss at operation or to ascertain the amount of blood replacement needed

Table 10 *Blood loss Determined by Dry Weighed Sponge Method Lobectomy for Tuberculosis*

(Forcer J H *et al* Arch Surg 65 88 1954)

	Mean Averages	
No Patients	*Blood Loss* cc	*Blood Transfusion* cc
11	1,340	2,000

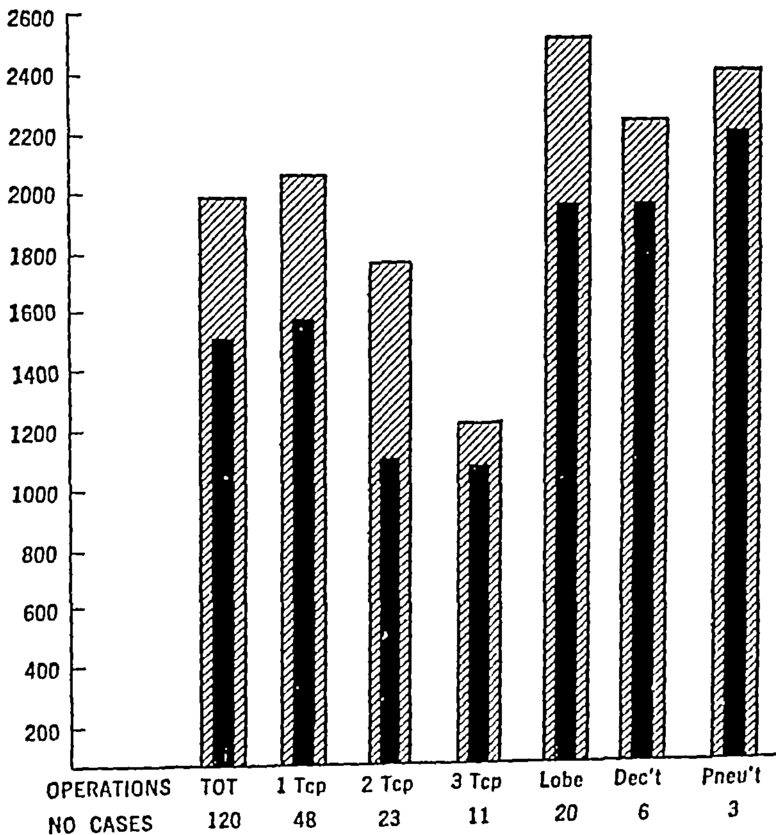
A summation of the pertinent data of these studies is depicted in Graph II These data indicate an apparently greater blood loss in thoracic surgical operations for pulmonary tuberculosis than that generally recorded The changes in blood volume values before operation and twenty four hours after operation do not it is believed reflect exactness in estimating blood loss Other factors such as etherization surgical trauma probable failure of the dye to enter rapidly all compartments of the vascular system and the element of error in such determinations account for an appreciable variation in blood volume values This method therefore is not advised as a substitute for the valuable method of dry weighed sponge estimation of blood loss due to surgical operations Our observation indicates that blood volume estimations are approximately twice that calculated by the former method It is our belief based on these observations that a more accurate practical replacement therapy program in most thoracic surgical operations is feasible by employing the knowledge gained from both these methods It is recommended that replacement by whole blood in most thoracic surgical operations, cardiac excluded exceed by approximately 50 per cent that calculated as lost by the dry weighed sponge method The usual minimal requirements then for a first stage thoracoplasty should be approximately 1500 cc 1200 cc for second stage thoracoplasty and 1000 cc. for third stage Pulmonary lobectomy would require approximately 1500 to 2000 cc. of whole blood replacement Decortication would require if technically difficult 1500 to 2000 cc. and pneumonectomy would require 2000 cc

One should not employ blood transfusion without its actually being needed Its routine use for operations with little blood loss is not warranted

Duration of Operation. The duration of operation in the surgery of pulmonary tuberculosis presents no unusual considerations *per se* as the adherence to sound surgical principles predicates the time factor Haste is unwarranted and the unnecessary prolongation of the operation is equally undesirable There are wide variations in the time required by equally

competent surgeons in the performance of similar types of operations, and whether one is a rapid operator or a slow one is not the criterion for appraising that particular surgeon's capabilities I am not a fast operator and the time averages for me, operating with frequent changes in assistants, have been first stage thoracoplasty, two to two and one-half hours, second stage thoracoplasty, one and one-half hours, and lobectomy or pneumonectomy, four hours If the members of the operating team are constant over a period of several months or years, this time may be appreciably reduced

Graph II. Blood Loss in Surgical Procedures for Pulmonary Tuberculosis (Blood Volume Studies)



Hatched columns indicate amount of blood loss Black columns indicate amount of transfused blood Tcp indicates thoracoplasty, lobe, lobectomy, dec't, decortication, and pneu't, pneumonectomy

Previous Thoracic Surgery. As in other technical problems previous surgical operations on the same side of the chest increase the difficulties of subsequent thoracic procedures on that side The prior performance of an extensive thoracoplasty is the most commonly encountered problem The regeneration of the bony thorax and the dense adherence of the lung to the chest wall makes any subsequent thoracic procedure on that side more time-consuming and hazardous It is a marked achievement of the past few years that secondary operations have almost been eliminated in the treatment of pulmonary tuberculosis

Postoperative Care *Coughing* Attention to details is particularly important in the postoperative care of patients treated surgically for pulmonary tuberculosis The expectoration of secretions is best accomplished by aiding the patient to sit in bed and as an attendant supports the lower portion of both sides of the thorax the patient makes vigorous efforts to expectorate the secretions. This is accomplished at one-hour intervals during the first twenty four hours after operation then every two hours for the following twenty four to forty-eight hours The patient is usually able to carry on unassisted after the first two or three days.

Nasotracheal Aspiration. Nasotracheal aspiration of retained secretions is simple to accomplish and frequently indicated Using a fairly stiff catheter (16 to 18 F) the patient is placed in a semi-sitting position with the back supported and the head and neck dorsally extended The lubricated catheter is quickly passed through the nose into the pharynx without suction. The patient is instructed to take a deep breath and during inspiration the catheter is passed into the trachea If the patient gags the catheter is in the esophagus, not in the trachea Suction is applied intermittently as the catheter is passed into the tracheobronchial tree Secretion from both sides should be removed

Bronchoscopic Removal of Retained Secretions In some patients effective aspiration can be accomplished only by means of instrumentation with the bronchoscope. This may often be best accomplished in the patient's room without removing him from his bed

Removal of Intercostal Tube Daily roentgenograms are studied and the intercostal tubes removed after the remaining lung tissue has expanded to fill the hemithorax. This is usually accomplished within forty-eight hours after operation Intercostal tube drainage is usually not carried out following pneumonectomy

Auscultation Frequent auscultation of the chest is essential in ascertaining the presence of retained tracheobronchial secretions and the aeration of the lung

Thoracentesis Thoracentesis is seldom necessary if intercostal tube drainage is established Air replacement following thoracentesis is not practiced If pneumonectomy is performed thoracentesis sufficient to keep the hemithorax dry is the practice which we have followed during the first three weeks after surgery then the frequency of thoracentesis is decreased and pleural fluid gradually allowed to accumulate

Suction Suction applied to the intercostal tubes in my opinion is seldom required If after forty-eight hours the remaining lung tissue has not filled the hemithorax suction not to exceed 20 mm of water is applied to the intercostal tubes Several pump devices are excellent however we have found that the simple connection with the water faucet in the adjacent bathroom with a water trap bottle interposed between the suction and drainage bottle is effective

Control of Pain The amount and frequency of narcotics should be scrutinized These patients are often debilitated and doses of 015 gram of morphine or 0.10 gram of demerol are excessive Each patient should be carefully appraised in prescribing the postoperative orders. The cough reflex must not be suppressed yet the pain should be minimized by the use

Table 11. Electrolyte Changes Following Thoracic Surgery—20 Patients*

(Aronstam, E. M. *et al.*, Ann. Surg. *137*, 316, 1953)

Electrolyte	Preop Mean	1st Postop Day Mean	1st Postop Day % Chg	4th Postop Day Mean	4th Postop Day % Chg	11–12 Postop Day Mean	11–12 Postop Day % Chg
Serum potassium (mEq.)	4.8	4.8	0.0	4.6	−4.2	5.1	+6.2
Serum sodium (mEq.)	138.0	133.0	−3.6	140.0	+1.4	142.0	+2.9
Serum chlorides (mEq.)	106.0	105.0	−0.9	102.0	−3.8	106.0	0.0
Urinary potassium mEq./24 hr	59	56.2	−4.8	34.6	−41.3	53.6	−9.1
Urinary sodium mEq./24 hr	195.6	69.6	−64.4	103.8	−46.9	161.3	−17.5
Urine output ml./24 hr	1593.0	788.0	−50.5	1633.0	+2.5	1540.0	−3.3
Oral intake ml./24 hr	2137.0	1567.0	−26.7	2562.0	+19.9	2329.0	+8.9

* Changes relative to preoperative levels used as norm, shown with per cent change based on the group respective arithmetic means

Table 12. Changes in Hematological Levels Following Thoracic Surgery in 20 Patients*

(Aronstam, E. M. *et al.*, Ann. Surg. *137*, 316, 1953)

Blood Studies	Preop Mean	1st Postop Day Mean	1st Postop Day % Chg	4th Postop Day Mean	4th Postop Day % Chg	11th Postop Day Mean	11th Postop Day % Chg
Blood volume cc./kg.	80.4	75.4	−6.2	77.9	−3.1	85.0	+5.7
Plasma volume cc./kg.	43.0	38.7	−10.0	43.5	+1.1	47.8	+11.1
Hematocrit mm./%	47.2	48.7	+3.2	43.7	−7.4	44.3	−6.1
Hemoglobin Gm.	16.1	15.7	−2.5	14.8	−8.1	15.1	−6.2
Red blood cells (10^6 = M)	5.20	5.26	+1.1	4.71	−9.4	4.85	−6.7
Proteins Gm. %	6.2	6.2	0.0	6.05	−2.4	6.2	0.0
Total circulating Prot. Gm.	182.8	158.5	−13.3	176.1	−3.7	196.6	+7.6
Carbon dioxide combining Power Vol. %	68.9	62.8	−8.8	68.0	−1.3	64.8	−5.9

* Changes relative to preoperative levels used as norm, shown with per cent change based on the group respective arithmetic means

of drugs The blocking of the intercostal nerves as the wound is being closed has not been particularly effective in our hands.

Fluids The adult patient who has undergone thoracic surgery exclusive of operations on the esophagus is able to take sufficient fluids by mouth during the early postoperative period to insure an adequate urinary output A twenty four hour oral intake averaging 2,200 cc is sufficient to insure a twenty-four-hour urinary output of 300 to 800 cc and intra venous fluid therapy is seldom indicated postoperatively if adequate blood replacement therapy is accomplished during surgery Body fluid shifts in patients undergoing thoracic surgical procedures have been studied by Major Elmore M Aronstam Medical Corps of our staff [2] The electrolyte and hematological changes are depicted in Tables 11 and 12

The amount of whole blood transfusion given during the surgical procedures were larger than those generally reported and approximated a 50 per cent increase above the estimated blood loss as determined by the dry weighed sponge method [3] It was significant to note that with no further blood transfusions the mean average blood volume was slightly above the preoperative mean by the twelfth postoperative day The patients studied did not show significant depression of serum sodium serum chloride and CO_2 combining power or alterations in the potassium levels

Two other significant features of this study are first there was a rather marked sodium retention in the first few days after operation approaching the preoperative levels by the twelfth postoperative day second was the *almost constant increase in extracellular fluid during the early post* operative days again returning to normal by the twelfth day after operation The expansion of the extracellular fluid space in the absence of salt and water infusions and in the presence of renal salt retention is particularly significant in the thoracic surgical patient Those tuberculous or other patients with poor respiratory reserve are much more susceptible to the development of pulmonary edema if saline solutions are administered in the postoperative period [4] Therefore oral liquid intake and not intra *venous saline fluids, are given during the first twenty-four to forty-eight* hours thereafter soft foods and a regular diet are generally well tolerated

Antibiotics Instilled Intrapleurally It is an almost regular practice to instill penicillin 200 000 units and streptomycin 1 to 2 grams in the intrapleural space immediately following extirpative surgical therapy Because these substances in part at least will not remain in the thorax long if intrapleural drainage tubes are inserted their effect is of short duration and probably of questionable value Their administration systemically is continued in the immediate postoperative period the dosage of streptomycin usually being increased to 1 gram daily for fourteen days and penicillin 600 000 units daily for a similar period Streptomycin is then continued as in the preoperative period and penicillin discontinued

Physical Medicine Aids I am indebted to Captain Robert J Gosling Medical Corps, U S Army Physical Medicine Service Fitzsimons Army Hospital for the following section regarding the role of physical medicine in the tuberculous thoracic surgical patients

General Physical treatment has become an integrated and important part of the total care of the tuberculous pre- and postoperative thoracic

patient at Fitzsimons Army Hospital. This plan of coordinated treatment has been evolved through the planning and cooperation of the medical, surgical, and physical medicine services, and has been in effect, with few modifications, for the past seven years The tuberculous surgical case has (1) a debilitating disease, (2) a lowered vital capacity and (3) a surgically altered body These very factors define the needs, as well as the physical limitations, of the patient Their coexistence, at odds with each other, requires careful consideration and immediate management to assure optimal function in the months and years far removed from the time of surgery The physical therapy program entails the minimal localized activity which will accomplish the desired results at the appropriate time In many cases, particularly in those who have had prolonged hospitalization, residual muscular losses and weaknesses are frequently only too obvious when the patient returns to his medical ward, to presume that maximal benefit from physical treatment has been attained while on the surgical ward. The limiting factor in treatment, as always, is the patient's disease Residual weaknesses suggest the need for further physical rehabilitation later when the patient's treatment program permits increasing activity [12 15,16,31,32]

Preoperative Considerations The preoperative evaluation and instruction by the Physical Medicine Service is very important The patient is evaluated by the physiatrist and instructed by the physical therapist several days prior to surgery During this period it is plausible and practical to develop an understanding with the patient concerning what he can do pre- and postoperatively to obtain optimal functional results and minimize deformity It is advantageous to take note of existing limitations and deformities Initial instructions concern the best postoperative position in bed, the principles of good body mechanics, the shoulder-mobilizing exercises to be performed at a later date, and the patient is impressed with the fact that the physiatrist and physical therapist can instruct, but that he himself must follow the instructions to derive benefit In the physical medicine management of these patients we are concerned primarily with preventing deformity, but where deformity is present, the same spirit of patient cooperation must be established

Operative Alterations With thoracoplasty a number of anatomical and functional patterns are altered (1) The balance of the neck is disturbed, allowing a lateral deviation of the head and neck toward the unoperated side The rigid points of attachment of the scaleni are separated from the first and second ribs, (2) the chest is deformed by the resection of the ribs, (3) a potential scoliosis is initiated at the time of surgery In the operative site certain muscles must be separated or retracted, some losing their points of origin and insertion The intercostals of the resected ribs no longer have a skeletal attachment, thereby losing their balancing force on the thoracic cage and, indirectly, on the spine The erector spinae may be retracted and incised during the operative procedure, and (4) shoulder function is impaired indirectly due to the temporary or permanent loss of scapular stability resulting from the surgical sectioning or stretching of the middle and lower trapezius, the latissimus dorsi, the rhomboids, and the serratus anterior After adequate time for healing,

the sectioned or stretched muscles require protection and meticulous muscle reeducation in order to restore optimal function

Postoperative Considerations Postoperatively there are many factors which aggravate deforming tendencies of these surgical alterations With the temporary loss of contractility of the musculature involved in the surgery the uninvolved and now unopposed muscles of the shoulder girdle—namely the upper trapezius the pectorals and the levator scapulae—exhibit almost constant increased tonus producing an involuntary elevation and anterior displacement of the shoulder This may represent a reflex attempt on the part of the body to splint and protect the operated area the scapula may impinge periodically on the upper remaining rib or it may be that these muscles are called upon to stabilize the neck from its deviation toward the normal side It is to be noted at this point that the scoliosis which may develop has its primary curve in the cervico-dorsal area convex to the operated side eventually compensated by a secondary cervical curve above and a lumbar curve below The anterior shoulder position is produced by the depression in the chest wall created with the resection of the ribs the collapse of overlying soft tissues and the disturbed muscle balance. This brings the scapula forward carrying the clavicle and humerus with it This position places the lower scapular muscles at a mechanical disadvantage in certain of their movements A bulky pressure dressing placed high beneath the axilla will contribute temporarily to this displacement of the shoulder as does the presence of the drainage tubes which are to be removed later

Therapeutic Approach It is with this complexity of functional alterations in mind that the physiatrist and the physical therapist present a concrete and objective therapeutic program to the patient pre and postoperatively The objectives as presented preoperatively are repeatedly emphasized to the patient Optimal position in bed is that of over-correction toward the side of surgery This includes alignment of the lower trunk and hips evenly in bed with the upper trunk and operated shoulder consciously depressed toward the operated side. The head and neck should be aligned with the lower trunk or tilted moderately toward the operated side also The attempt is to reverse the cervico-dorsal curve and to minimize the pull upward on the muscles about the operative site As early as possible after the surgery the physical therapist initiates shoulder motion The early passive and assistive movement of shoulder abduction flexion and rotation are extremely important in re-establishing a normal pattern of function It is necessary to encourage the use of the involved muscles and to minimize the overactivity of the uninvolved muscles All of the altered mechanisms which have been described above tend to interfere with the normal return of function of the scapulo-thoracic muscles directly affected by the surgery and with the eventual return of a normal functional shoulder joint It has been our policy to encourage motion only to 90 degrees at the gleno-humeral joint until the sutures have been removed following which complete range of motion is the objective The patient is treated twice daily seldom longer than ten minutes at a time As the patient is allowed out of the bed the treatment period is spent before the full length mirror on the ward The upright position necessitates progressive modi

patient at Fitzsimons Army Hospital. This plan of coordinated treatment has been evolved through the planning and cooperation of the medical, surgical, and physical medicine services, and has been in effect, with few modifications, for the past seven years. The tuberculous surgical case has (1) a debilitating disease, (2) a lowered vital capacity and (3) a surgically altered body. These very factors define the needs, as well as the physical limitations, of the patient. Their coexistence, at odds with each other, requires careful consideration and immediate management to assure optimal function in the months and years far removed from the time of surgery. The physical therapy program entails the minimal localized activity which will accomplish the desired results at the appropriate time. In many cases, particularly in those who have had prolonged hospitalization, residual muscular losses and weaknesses are frequently only too obvious when the patient returns to his medical ward, to presume that maximal benefit from physical treatment has been attained while on the surgical ward. The limiting factor in treatment, as always, is the patient's disease. Residual weaknesses suggest the need for further physical rehabilitation later when the patient's treatment program permits increasing activity.[12,15,16,31,32]

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fications of the program, with continued emphasis to restore good body mechanics and normal shoulder function. Here it should be noted that these objectives should be attained as completely as possible before each successive stage of surgery Thus, the physical treatment program is one which must be appropriate for each individual's needs and to his disease

The problems after thoracotomy without thoracoplasty are not the same, nor as complex, but the consequent deforming tendencies are equally significant to the patient The difference is largely the difference in the surgical alteration of the functional anatomy Again we have the sectioning of muscles of the posterior and posterolateral aspect of the chest, although usually to a lesser degree Again there are the stretched muscles, the splinting of pain, the healing scar, the wound dressing and frequently the drainage tubes However, the thoracic cage remains intact Frequently the procedure involves the removal of all or part of a lung, lowering the vital capacity, and the chest may be flattened and inactive With this procedure the head and neck may be tilted laterally toward the affected side, later to become part of a compensated scoliosis with the shoulder tending to drop forward and downward on the affected side The overcorrected bed position toward the unoperated side is stressed in these patients Shoulder mobilization progresses much along the same lines as after thoracoplasty, but because of the vast differences in degree of structural change, re-establishment of a normal functional pattern is much simpler and requires much less time

We have not been teaching diaphragmatic breathing routinely in thoracic surgical procedures for tuberculous patients This has been reserved for selected patients showing undue anxiety with shortness of breath and excessive chest movement, usually producing shallow, rapid, apprehensive, and ineffective respirations It has proved most gratifying in a repeated number of cases We do give breathing instructions to the patient undergoing decortication where the objective is re-expansion of the involved lung

The physical therapist must be equally aware of the contraindications to his treatment Among these are (1) fever of 100° F or more, (2) hemoptysis, (3) dyspnea, (4) wound infection, (5) cardiac dysfunction, and (6) any other untoward change in clinical status Exercises are avoided that will increase the rate of respiration or produce fatigue Each patient receiving physical treatment is seen at weekly intervals on the ward by the physiatrist Progress notes are recorded, noting the gains as well as any deforming tendencies in the patient In this way any indicated modifications in treatment may be discussed and further therapy prescribed by the physician

The administration of physical treatment to the patient with tuberculosis is still comparatively new, but there has been sufficient time since the introduction of these techniques to permit an accurate appraisal of their effectiveness in preventing and overcoming physiological losses and to prove their innocuous effect on the tuberculous process itself Clinical experience has shown that when selected therapeutic exercises and procedures are properly administered and supervised they do not interfere with surgical therapy, do not increase the excursion of the expanded lung,

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Summary The summation of general considerations in the surgical therapy of pulmonary tuberculosis emphasizes the need for the same careful and meticulous attention to the requirements of properly indicated performed and postoperative supervision as does all surgery plus many special considerations demanded by the disease itself and the peculiarities of respiratory physiology

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Chapter

6

Experience With Collapse Therapy

General. The collapse therapy of pulmonary tuberculosis was the sheet anchor of surgical efforts prior to the era of chemotherapy. The procedures of collapse therapy were the best available and combined with properly supervised bed rest resulted in the arrest of the tuberculous disease in an appreciable percentage of patients.[1–5,7,8,10,12,13]

Extrapleural Thoracoplasty in Caseopneumonic Tuberculosis. *Characteristics.* The characteristics of acute caseopneumonic tuberculosis are those of a sudden onset, fever of 100 to 104° F, marked malaise and productive cough. A clinical diagnosis of pneumonia is often made and the tuberculous etiology is suggested because the patient fails to respond favorably to therapy. The roentgenographic findings of dense soft shadows are lobar or lobular in distribution. With cavity formation softening frequently develops and bronchogenic dissemination is common. Prior to the antibiotic era the mortality was appalling but with the availability of streptomycin this dismal outlook has been remarkably altered.

Early Application of Thoracoplasty. Early in the antibiotic era, 1947–1948, my associates and I decided to undertake thoracoplasty in patients whose first manifestations of pulmonary tuberculosis were of a caseopneumonic nature. The results were excellent.[illegible] Streptomycin was employed to hasten the resolution of exudative lesions and to lessen the danger of spread of the disease during and following thoracoplasty. Previous efforts in this direction, though at times considered encouraging, were generally poor and the practice had been largely discarded.[illegible]

Thoracoplasty was not carried out until there had been demonstrable resolution of the exudative components with improvement in clinical signs and symptoms. Decrease in cough and sputum production, a change from a febrile to an afebrile course of at least several weeks duration, a gain in weight, and a feeling of well being, are the clinical improvements awaited. Streptomycin is credited with inducing these beneficial effects, thus permitting the patient to undergo thoracoplasty much earlier than heretofore recommended. Further experience in the use of the chemotherapeutic agents has led to enhanced knowledge of dosage, sensitivity and resistance. The result has been that the indications for the early application of thoracoplasty in caseopneumonic tuberculosis have given way to other even more effective surgical therapeutic efforts. However, the feasibility of the early application of surgery in pulmonary tuberculosis had been established, and six to twelve months of proper bed rest and chemotherapy are generally

adequate preparation for surgical therapy in active pulmonary tuberculosis

Effect of Chemotherapeutic Agents Streptomycin was the only effective drug available during 1947–1948 Its exact mode of action, and indeed that of analogous and complementary agents, is still not thoroughly understood It was recognized early that streptomycin exerted its most favorable effect in the resolution of exudative lesions, such as those which characterize the caseopneumonic variety of the disease This feature was immediately used in the preparation of patients for surgical therapy The resolution of the exudative elements of pulmonary tuberculosis in response to streptomycin often leaves the cavitary areas visible roentgenographically It is my belief that these cavitary processes should be treated surgically as soon as their persistency becomes established In this way one avoids the production of the hard, destructive, fibrous lesions, in which anatomical and pathological changes deter healing, resulting in prolonged disease, and increased hazards of dissemination and bleeding.

Age, Race, Sex, and Known Duration of Disease Prior to Thoracoplasty These data demonstrate the propriety of the application of thoracoplasty early in caseopneumonic tuberculosis The patients were principally young adults, none were over forty years of age, only two were females, the proportion of Negroes was very high, 51 4 per cent, or approximately four times that of the entire group on whom surgical therapy was performed None of the patients were known to have had the disease more than eighteen months prior to thoracoplasty In one-third the disease duration was six months or less, in 43 per cent the duration was seven to twelve months, and the average duration was nine months All were members of the Armed Forces, or dependents thereof, and the estimation of the date of onset was highly accurate, as patients with symptoms characteristic of this type of disease are immediately hospitalized

These data have increased significance when comparisons are made with the era before chemotherapy The decreasing of the interval from onset of disease to surgical therapy is of great economic significance alone, and this factor is slight in comparison to the beneficial effect on the patient in his fight for recovery I know of no other similar group of patients, in whom the results were comparable, who experienced such a short interval from onset to thoracoplasty The short period of disease duration weighed heavily in our decision to extend the indications for surgery early in the antibiotic era The percentage of tuberculous patients presently undergoing surgery for pulmonary tuberculosis approximates 25 per cent of all admissions Again, these data are fascinating when one recalls that prior to 1946 the duration of disease before admission to a tuberculosis sanatorium was often prolonged Only 5½ per cent of the patients admitted to Rutland Sanatorium, 1927–1946, had had the disease less than one year[4] As 82 4 per cent of the 34 patients followed reached a stage of inactive disease, it appears that the factors of age and race were not appreciable (Table 13) With such satisfactory results in patients in whom the disease process was not one previously considered suitable for thoracoplasty, the early application of surgical therapy received fresh impetus (Figs 29 and 30)

Table 13 Age Race and Sex. Acute Caseopneumonic Tuberculosis Treated by Thoracoplasty 35 Patients

Age					
Years	*Per cent*	*Race*	*Per cent*	*Sex*	*Per cent*
18–20	17	White	46.0	Male	94.3
21–30	60	Negro	51.4	Female	5.7
31–40	23	Indian	2.6		

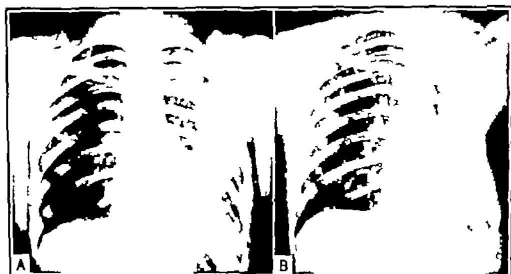


FIG 20 —Acute caseopneumonic tuberculosis treated by thoracoplasty and streptomycin. *A* August 11 1947 Negro soldier age 27 Sudden onset of illness July 23 1947 with fever severe night sweats, productive cough and rapid loss of 27 pounds in weight. Sputum positive for tubercle bacilli Diffuse parenchymal infiltration throughout left lung No streptomycin. *B* April 8, 1948 Six weeks after completion of a four-stage, nine-rib thoracoplasty Streptomycin alone, 2 grams every third day for total dosage of 84 grams. Marked clearing of the exudative lesions bilaterally occurred prior to thoracoplasty The wide distribution of residual lesions throughout the lung was considered an indication for thoracoplasty rather than extirpative surgery which would have required pneumonectomy Onset to thoracoplasty seven months. Sputum has been negative since thoracoplasty a period of more than five years. Patient left the hospital against medical advice seven months after thoracoplasty but fortunately he had no relapse and has remained well Since March 1950 he regularly attended school six hours a day for one year and has been working 40 hours a week for more than two years.

Extent of Disease and Cavitation Bilateral parenchymal involvement as determined by clinical observations and serial roentgenographic studies were present in 86 per cent of the patients Cavitation representing the remnant of the sloughing area which has been expectorated is difficult to estimate as to size The ordinary measurement of the roentgenographic shadow interpreted as cavitation is probably as satisfactory as any method for this estimation Cavitation was demonstrable roentgenographically in all patients the size varying from 1 to 4 centimeters in diameter and

multiple cavities were present in approximately half of the patients Eleven per cent had cavitation in the less involved lung

Endobrachial Tuberculosis All patients on whom surgery is contemplated should be examined bronchoscopically to determine the presence or absence of involvement of the larger bronchi Bronchoscopy was performed on 24 of these patients but only 4 demonstrated evidence of endo-

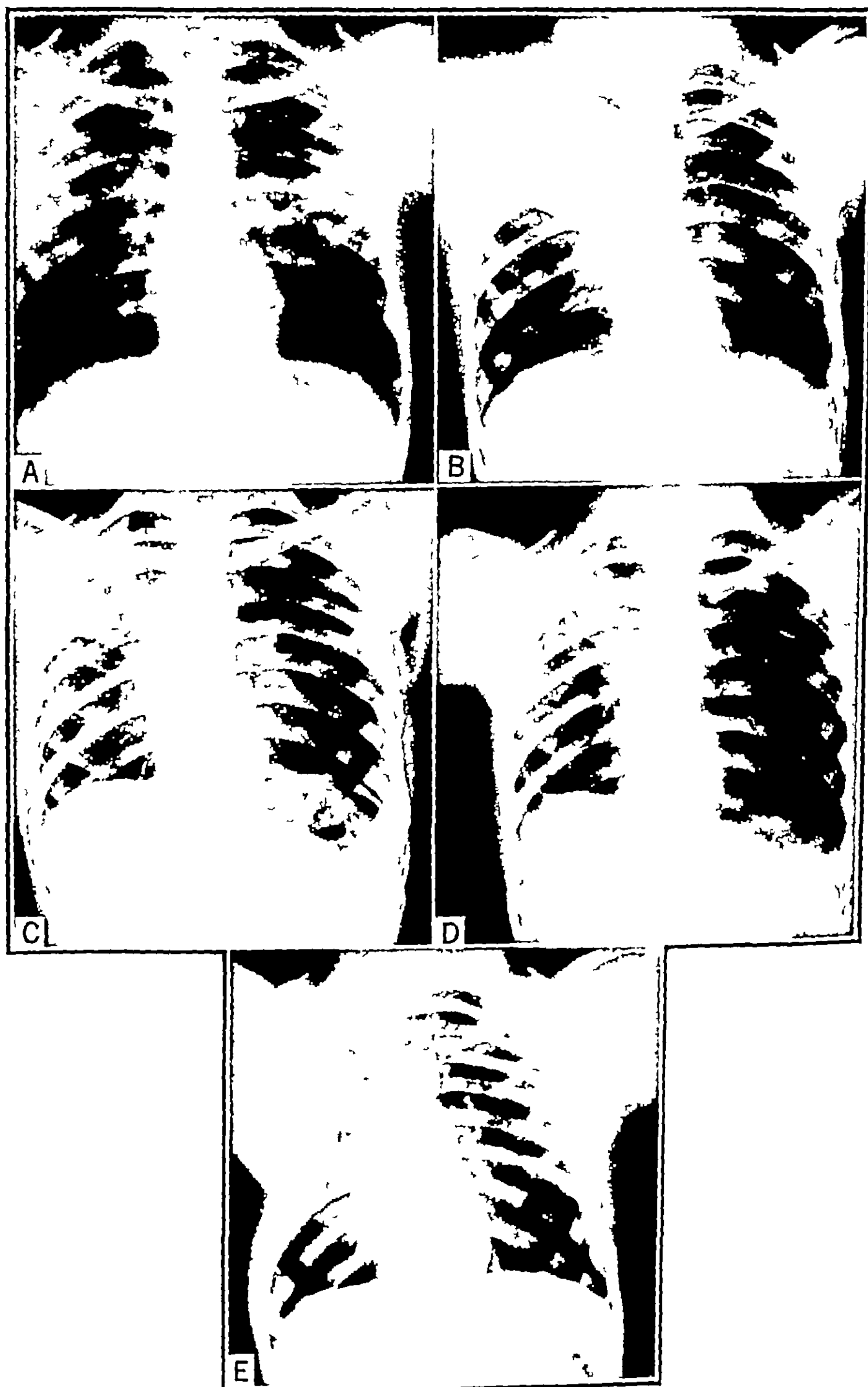


Fig 80 Legend on opposite page

bronchial disease On reexamination prior to thoracoplasty the lesions had healed

Plan for Use of Streptomycin The streptomycin dosage was much more massive than that now employed and in 80 per cent no other drug was combined with streptomycin This then was a real test of the effectiveness of streptomycin in preparation for surgery the prevention of spread of the disease associated with surgery and a measure of its effect on the disease following operation The dosage of streptomycin followed the pattern of 1 to 2 grams daily for one hundred and twenty days or longer, or 1 to 2 grams every third day for similar periods (Tables 14 and 15) The fear of the development of resistance to streptomycin by the patient s organisms was entertained but as 83 per cent of the patients were operated upon in 1947 and 1948 the true significance of this phenomenon was not appreciated In view of later studies it is of interest that streptomycin sensitivity studies were made on 57 per cent of the patients at the time of thoracoplasty and in 90 per cent of those studied the tubercle bacilli were sensitive to streptomycin

Table 14 Streptomycin Dosage Acute Caseopneumonic Tuberculosis Treated by Thoracoplasty 35 Patients

Less than 100	*Dosage in Grams*			
	101–200	*201 300*	*301–500*	*500+*
20%	48 6%	11 4%	14 3%	5 7%

Length of Hospitalization Persons with pulmonary tuberculosis who are treated in a properly run hospital devoted to the care of tuberculous patients have a better chance of regaining their health and remaining well

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FIG 30 —Acute caseopneumonic tuberculosis treated by thoracoplasty and bed rest. Streptomycin added ten months after onset. Patient well. *A* November 6 1945 Negro soldier male, age 21 Moderate bilateral parenchymal infiltration Four days later he was examined for separation from the Army and indicated that he had been ill one week with fever cough and upper respiratory infection. He was hospitalized and the sputum was positive for tubercle bacilli. *B* January 22 1946 Consolidation, upper half of right lung, fever 100–104° F spontaneous pneumothorax, right, December 20 1945 Lung has reexpanded. No streptomycin *C* April 2 1946 Admission to Fitzsimons Army Hospital. Extensive cavitation, right upper lung field, 60 cc sputum daily occasional vomiting, headaches, and marked malaise. Considerable resolution of pneumonic lesions has occurred There has been 30 pounds loss in weight since onset, November 1 1945 No streptomycin. *D* September 9 1946 After 90 days of streptomycin 2 grams daily considerable clearing bilaterally Dizziness due to streptomycin therapy has been manifested. Streptomycin continued. *E* January 26 1950 Three years post thoracoplasty Fifteen months continuous hospitalization after thoracoplasty No other hospitalization Sputum continuously negative since operation. Total streptomycin dosage was 373 grams. Slight dizziness continues February 1953 patient well and had a work capacity of 40 hours a week.

than those with comparable disease who are not cared for in such a hospital In addition, patients who are intermittent in their hospital stay do not do as well as those whose hospitalization is continuous The advent of streptomycin and other chemotherapeutic drugs has not altered our basic concept in this matter, although experience may demonstrate that an appreciable reduction is feasible in the length of required hospitalization Ideally, that period should extend from the detection of the disease until it is inactive The length of continuous hospitalization prior to and after surgery is listed in Table 16

Table 15 ***Duration of Streptomycin Therapy. Acute Caseopneumonic Tuberculosis Treated by Thoracoplasty. 35 Patients***

Daily, 120 Days or More	*Every Third Day for 120 Days or More*	*Combined with Other Drugs*
1–2 grams or more	1–2 grams or more	
74 3%	25 7%	14 3%

Table 16 ***Length of Continuous Hospitalization Thoracoplasty in Acute Caseopneumonic Tuberculosis. 35 Patients***

	Before Thoracoplasty		*After Thoracoplasty*	
	Months	*Per cent*	*Months*	*Per cent*
	–6	25 7	–6	5 7
	6–12	42 9	6–12	40 0
	13–18	25 7	13–18	25 7
	19–36	5 7	19–36	28 6
Average		9 Months		14 Months

Other Surgery The original concept of this study adhered to the principle that cavity closure and healing following thoracoplasty would probably not be accomplished in a high percentage of patients, and that further surgery, especially extirpative measures, would be necessary at a later date It was, therefore, somewhat of a surprise upon reviewing this group of patients to note that only 2 have had subsequent extirpative measures accomplished on the thoracoplasty side In 1, the removal of the thoracoplasty-collapsed upper lobe and a segmental resection of the dorsal division of the lower lobe on the thoracoplasty side was performed, sixteen months after thoracoplasty The other patient had an upper lobectomy, removing a cavitary lesion In both patients the sputum had continued positive after thoracoplasty, and became negative after removal of the diseased areas A third patient had a segmental resection of the upper lobe on the side opposite to the thoracoplasty thirty-five months after the original operation Again the sputum was positive prior to excision of the lung tissue, and has subsequently been persistently negative

Complications The assessment of complications includes all, however remote, and those that developed during the long term follow-up period Although it would be reasonable to expect a high rate of spread of the dis-

ease to other portions of the lung following thoracoplasty this complication occurred in only two patients or 5 7 per cent Other complications related to 108 thoracoplasty operations performed on the 35 patients were atelectasis requiring bronchoscopic aspiration of retained tracheobronchial secretions 1 gastric bleeding 1 homologous serum jaundice 1 hydropneumothorax 3 thrombophlebitis 1 and wound infection 2

Sputum Conversion Positive sputum became negative in 25 patients within six months after operation Three converted within one year one of whom had lobectomy after thoracoplasty failure The total in whom the sputum has converted is 28 of the 34 patients followed or 82 4 per cent a highly satisfying result in the surgical efforts directed toward this type of pulmonary tuberculosis

Follow-up Data The follow-up data in this group are 97 per cent complete. Twenty-eight per cent were followed for more than five years after thoracoplasty and none for less than eighteen months Twenty nine or 83 per cent of these patients were operated upon during 1947 or 1948 Two were operated upon in 1949 3 in 1950 and 1 in 1951

Results There was no operative mortality Three patients are dead and 3 continue to have positive sputa Thus of the total of 35 patients treated 34 were followed During this early period of the streptomycin era an era in which galloping consumption was treated by streptomycin in preparation for thoracoplasty 28 or 82 4 per cent enjoyed clinical recovery sputum conversion and entered a state of apparent secure disease inactivity a circumstance seldom experienced prior to streptomycin Twenty-seven patients, 77 per cent are working regularly attending school performing the usual duties of a housewife or doing part time work of at least twenty hours weekly One patient has had consistently negative sputum since thoracoplasty but has continued to require hospitalization because of mental disease The final status of 1 patient is not known

Review of Deaths A review of the 3 deaths in this group emphasizes the importance of full participation in therapy by the patient the desirability of a longer period of chemotherapy than was used early in this era and the appreciation of how much is yet to be learned about this interesting disease and its treatment (Fig 31)

Appraisal of This Experience and Its Influence on the Surgical Therapy of Pulmonary Tuberculosis The reduction of the volume of the lung achieved by thoracoplasty is a feasible method to promote healing in caseopneumonic tuberculosis if resolution of exudative lesions is first effected through the use of chemotherapy The application of thoracoplasty early averaging nine months from disease onset permitted the collapse of cavities having thin walls. The replacement fibrosis which had occurred was probably minimal The effective lessening of sputum production due to chemotherapy is beneficial in decreasing the chance of spread of the disease during and immediately after thoracoplasty This early application of thoracoplasty has established a lasting benefit which further encouraged the earlier use of surgical therapy in pulmonary tuberculosis and was a forerunner to the wide use of extirpative surgery

This effort in surgical therapy was undertaken and largely completed during the early era of streptomycin therapy It now seems fortunate that

the knowledge accrued in the order it did We know now that very large doses of streptomycin are beneficial, but comparable effects are obtainable with much smaller doses Thoracoplasty, as a seven or eight or more rib removal with its inherent thoracic deformity, may now be almost deleted from our attack on uncomplicated pulmonary tuberculosis Extirpative

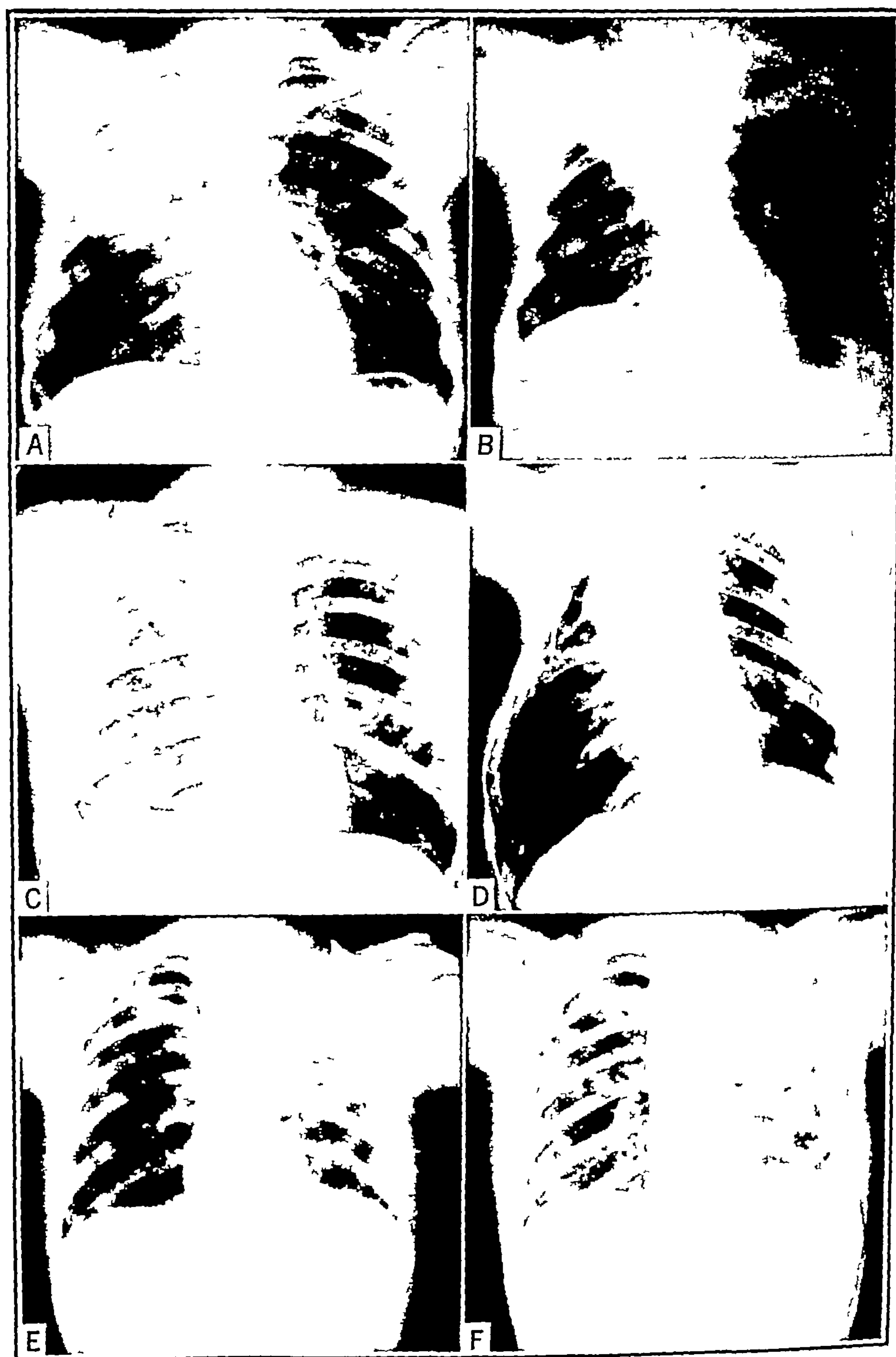


Fig 31 Legend on opposite page

surgical methods are preferable and where needed a smaller thoracoplasty space closing operation may be performed

Extrapleural Thoracoplasty in Fibrocaseous Tuberculosis *Characteristics* The distinction between fibrocaseous caseopneumonic, and caseofibrous types of pulmonary tuberculosis is that of a degree which may be slight or considerable In the fibrocaseous type the caseous element predominates with the fibrous tissue being readily evident The onset of symptoms is not sudden and one is seldom able to fix a specific date initiating the patient s illness There is a gradual onset often with slight fever mild cough sputum production and a rather insidious loss of weight The blending of the types is relative and many borderline decisions for purposes of classification become necessary (Fig 32)

Indications The indications for thoracoplasty employed in the 70 patients in this group have been relatively clear namely the application of thoracoplasty as soon as the resolution of exudative lesions has reached its maximum and before the chemotherapeutic agents have lost their effectiveness *i e* before resistance has developed There is only time loss disease progression and less opportunity of obtaining a favorable result if thoracoplasty is deferred until the lesions become hard and destructive The effectiveness of the use of streptomycin combined with other drugs such as para aminosalicylic acid for six months or more is resulting in further resolution of the tuberculous lesions often leaving a residual focus much smaller in extent than the original area of disease Such lesions are now being treated surgically by segmental resection without thoracoplasty

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Fig 31 —Acute caseopneumonic tuberculosis treated by thoracoplasty and streptomycin. Patients died. *A* January 6 1947 Negro male age 40 Onset July 11 1946 Extensive disease right upper lobe *B* September 15 1947 Admission to Fitzsimons Army Hospital and four months before thoracoplasty Marked contraction upper right lung field No streptomycin Later received a total of 184 grams of streptomycin. Remained in hospital 14 months after two stage five-rib thoracoplasty performed during January and February 1948 Comment It was 18 months from onset to thoracoplasty In retrospect it may have been better to have treated this patient by right upper lobectomy and a five-rib thoracoplasty Failing to remove the lobe originally it was recommended one year after thoracoplasty and unfortunately the patient declined. The autopsy report has not been obtainable *C* July 15 1946 White, soldier age 19 Ill 15 days. Far advanced bilateral disease *D* August 1 1950 One month prior to death Marked involvement upper left lung field. Thoracoplasty three stages, right, March and April, 1947 Total streptomycin, 172 grams Comment Sputum remained positive and the patient left the hospital against medical advice four months after thoracoplasty and had no further hospitalization Disease progression resulted in death *E* September 15 1947 Negro soldier age 19 Ill three months Admission to Fitzsimons Army Hospital. Extensive caseopneumonic involvement, left. Streptomycin started total dosage 181 grams *F* January 7 1948 One day prior to thoracoplasty Slight clearing Comment The patient was frequently uncooperative, violating hospital rules and being absent without permission Sputum remained positive. Death occurred 15 months after thoracoplasty during a severe hemoptysis At the present time chemotherapy would be employed for a much longer period, 12–18 month prior to surgical therapy

and with results exceeding the most exemplary of the pre-chemotherapy era

Pneumoperitoneum led the list of other collapse measures applied in these patients, with artificial pneumothorax therapy second Contralateral pneumothorax was maintained during the operative stages of thoracoplasty in 12 5 per cent Certain particular indications for surgery are present in relation to other collapse measures An ineffective artificial pneumothorax is such an indication (Fig 33)

Plan for Use and Effect of Chemotherapeutic Agents As this type of disease is more exudative than fibrous, the resolution of the former lesions is enhanced by chemotherapy, and the patient becomes a suitable candi-

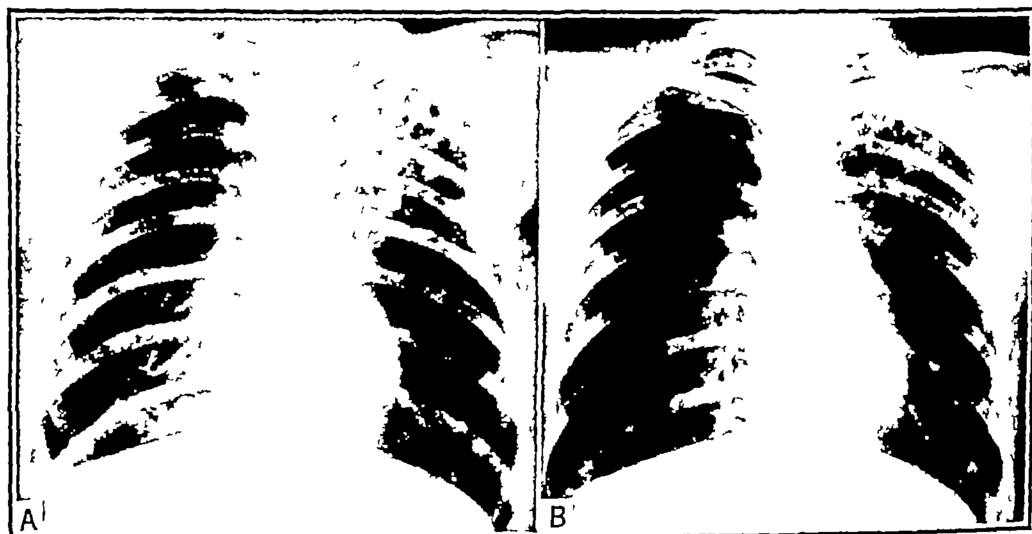


FIG 32 —Fibrocaseous tuberculosis *A* October 17, 1947 Cavitary lesion, left upper lobe, with considerable parenchymal infiltration *B* One day pre-thoracoplasty Considerable clearing after 60 days of streptomycin, 1 gram daily A three stage, seven-rib, thoracoplasty was performed seven months after onset He has been working 40 hours per week since January, 1952 Presently, a longer period of chemotherapy would be administered, extirpative surgery performed, and complete rehabilitation probably accomplished quicker with less thoracic deformity

date for surgical therapy within less than a year in a very large percentage of patients The overall chemotherapy plan as employed in 1949 was characterized by changing regimens and may be illustrated by a rather detailed presentation of an illustrative case Ten days after entering the Army a twenty-year-old white male was admitted to a military hospital on February 17, 1949, complaining of sore throat, a chronic productive cough, moderate night sweats, and a gradual loss of 22 pounds in weight In August, 1948, the patient had been informed that the interpretation of a chest roentgenogram revealed a "spot on the lung" However, he did not consult a physician after receiving this information Chest roentgenogram on admission to Fitzsimons Army Hospital revealed a 3 5 cm area of cavitation in the right upper lobe with considerable surrounding

infiltration and a 2 cm round lesion on the left (Fig 34) The sputum was positive for tubercle bacilli Strict bed rest was inaugurated and on March 17 dihydrostreptomycin 2 grams every three days was started and continued for thirty days The same therapy was restarted May 20 and continued until September 14 1949

The major dangers of cavitation are disease dissemination and bleeding Two weeks after discontinuing streptomycin there was clinical and roentgenographic evidence of reactivation or dissemination of the disease on the left (Fig 34C) Para-aminosalicylic acid 12 grams daily was started after the spread and continued to February 1950 Tibione was also given for one hundred and twenty days February to June of 1950 By June

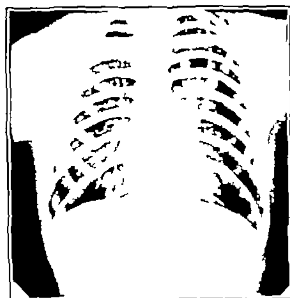


FIG 34 —Fibrocaseous tuberculosis treated by seven-rib three-stage thoracoplasty and chemotherapy *A* February 7 1947 Large cavity left, held open by adhesions or adherent lung. Pneumothorax ineffective. Lung reexpanded. Thoracoplasty resulted in disease inactivation

1950 there had been marked clearing of the lesions on the left and the lesions on the right were considered stable Streptomycin was begun again and a five rib two-stage thoracoplasty accomplished in July 1950 He was transferred to a private sanatorium in December 1950 and discharged as arrested March 25 1951 He is well and since January 1952 has been working regularly forty hours a week as a mail clerk in a large steel plant Sputum has been negative since thoracoplasty Total drug therapy was streptomycin 138 grams, tibione 22 650 mg and para-aminosalicylic acid 1048 grams.

It was sixteen months from the time the diagnosis was made until thoracoplasty was performed The severe dissemination of the disease occurred about eight months after the initial disease detection The clinical history strongly suggests a longer disease duration. More aggressive drug therapy would most likely have resulted in sufficient resolution of the original new lesions to have permitted surgery before spread or

reactivation of the tuberculous process to the opposite lung had occurred The danger of spread of tuberculosis, in our experience, has been much greater in the period prior to thoracoplasty than during or following this operation

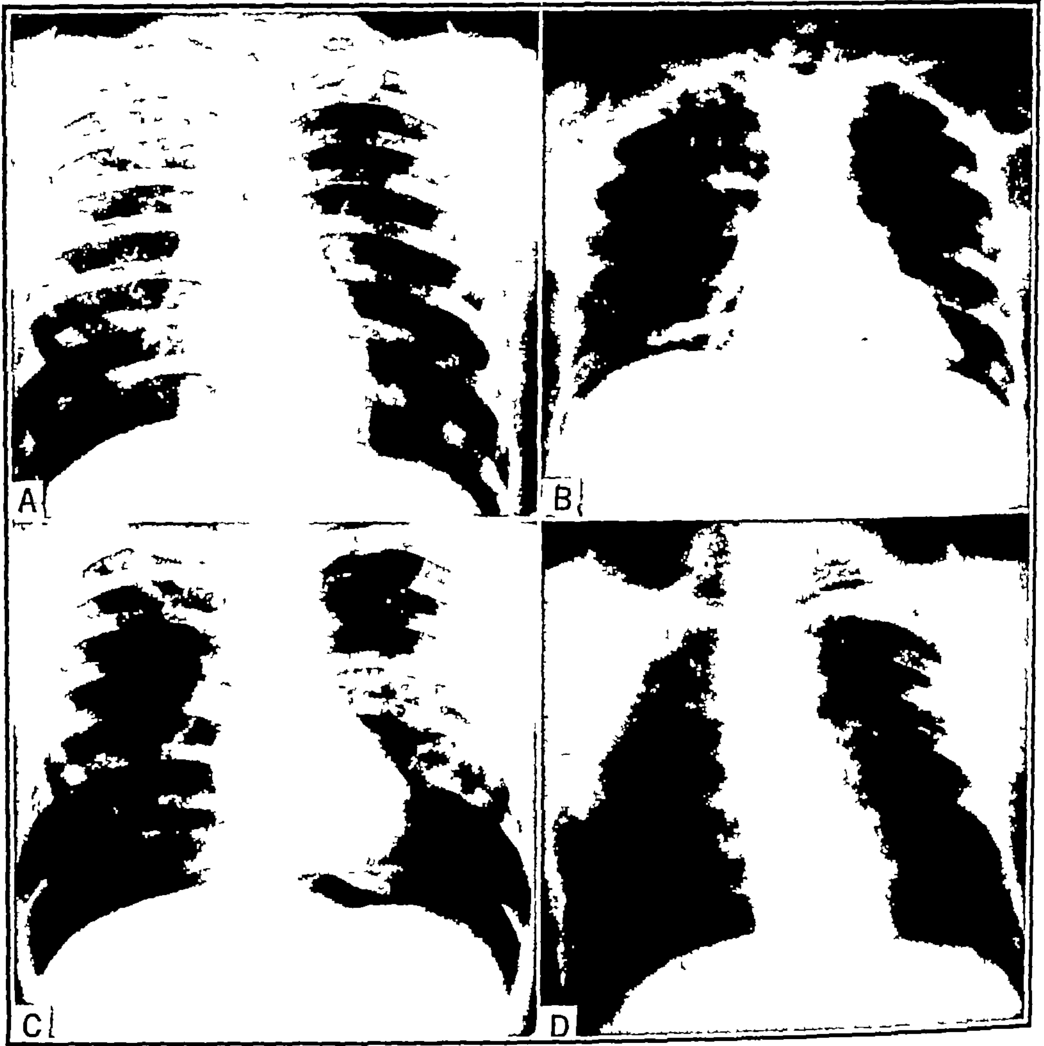


FIG 34 —Fibrocaseous tuberculosis treated by thoracoplasty and chemotherapy *A* April 13, 1949 Onset two months earlier Cavitary disease, right upper lobe There is also a lesion in left upper lung field *B* August 17, 1949 Artificial pneumothorax, right, proved ineffective and was later discontinued Dihydrostreptomycin, 2 grams being given every third day *C* October 3, 1949 Spread or reactivation in left lung Streptomycin discontinued two weeks prior to spread Artificial pneumoperitoneum is present *D* August 1, 1950 Thoracoplasty, right, five ribs, two stages, July, 1950 Patient well and working since January, 1952

The use of one collapse therapy procedure in relation to another has been a concern of thoracic surgeons for the past half century Many combinations have been employed [10] This patient received artificial pneumothorax, right, which was ineffectual, and pneumoperitoneum Steadily during the past several years there has been a decline in multiple collapse

therapy procedures carried out in a given patient This trend, I believe is good as it is now possible to approach most case problems by a planned surgical attack wherein one or more procedures performed within a short period comprise that plan.

Age Race Sex and Known Duration of the Disease Prior to Thoracoplasty Seventy-one per cent of the patients were thirty years of age or less The oldest patient was forty five and only 10 per cent were over forty years of age (Table 17) In the ten year age group the largest number were in the twenty-one to thirty year age period approximately 90 per cent were males. This closely parallels the relationship of the admissions of male and female tuberculous patients to Fitzsimons Army Hospital Seventy-seven per cent were white 19 per cent Negroes and 4 per cent were Japanese or American Indians The factors of race and sex were insignificant if the therapy advised was carried out by a cooperative patient

Table 17 Age of Patients Fibrocaseous Tuberculosis Treated by Thoracoplasty and Chemotherapy 70 Patients

	Per cent
Less than 21 years	17
21–30 years	54
31–40 years	19
41–50 years	10

Despite the insidious onset the estimate of the known duration is considered highly accurate because of the frequent employment of chest roentgenographic examination The average disease duration as determined by positive sputum prior to thoracoplasty was fourteen months Sixty-one per cent had had their disease for one year or less which is a favorable factor in collapsing cavities and the healing of tuberculous lesions by thoracoplasty Eighty-six per cent of this group whose disease duration was one year or less reached an inactive stage.

Extent of Disease In 92 per cent of the patients the disease was far advanced and in the remainder it was moderately advanced Seventy five per cent had bilateral involvement and ten patients had far-advanced cavitary disease in each lung In considering these data a rather striking fact is noted in that in 1952 three-fourths of the tuberculous patients treated at Fitzsimons Army Hospital by surgical methods were classified as having unilateral disease limited to the area above the level of the second costal cartilage at the time of operation It is thus evident that more and more persons with less and less active pulmonary tuberculosis are being treated surgically with increasingly satisfactory results and it seems reasonable to anticipate that this trend will continue

Cavitation The extent of the disease is closely related to pulmonary cavitation Cavitation was present roentgenographically in all patients some time prior to surgery The size of cavitation varied from the small areas of honeycombing to cavities of less than 5 cm in diameter Twenty-

five per cent had a single cavity which on roentgenographic examination measured 2 to 3 cm. in diameter.

Endobronchial Tuberculosis. Fifty-three of the 70 patients were examined bronchoscopically prior to thoracoplasty. There was no particular selection and 20.4 per cent of those examined had evidence of endobronchial tuberculosis. On being bronchoscoped six weeks to three months after streptomycin therapy, all exhibited either no evidence of or healed tuberculous lesions. This is in marked contrast to the 5 per cent having bronchoscopic evidence of endobronchial disease among the patients having localized lesions treated by extirpative surgery in 1952.

Length of Hospitalization. The patient wants and needs a target date or probable end-point to his hospital stay, as he ponders his decision regarding the recommendations advising surgical therapy. Indeed, the length of hospitalization is of concern not only to the patient, his family, and his physician, but also to the taxpayers, and is of considerable significance from the public health viewpoint. The patient, I believe, should remain in the hospital until the disease process is inactive three to six months as defined by the Standards of the National Tuberculosis Association. This is not readily transposed to a definite time period. However, our policy since 1947 has been to estimate the period required. The working plan has been to advise the patient that he remain in the hospital at least one year following completion of thoracoplasty. This goal has not always been achieved. Of 70 patients classified as having a fibrocaseous type of disease, 7 left the hospital against medical advice less than six months after completion of thoracoplasty. One left three weeks after the completion of a three-stage, seven-rib thoracoplasty procedure and he died four years later, death resulting from homicide. He had been followed regularly as an out-patient, the sputum had been repeatedly negative and necropsy revealed no evidence of active tuberculous disease. The other 6 patients have had inactive disease for periods varying from one to four years.

Sixteen patients were hospitalized less than six months before thoracoplasty. Two of these are dead, one as a result of progression of tuberculosis, and the other was the patient referred to above who was killed four years after thoracoplasty. Of the remaining, 13 are inactive and 1 continued to have positive sputum until a lobectomy was performed three years after thoracoplasty. Her sputum has been negative for a year since lobectomy. These data may suggest that the period of recommended hospitalization may be excessive. However, the number of patients involved is insufficient to warrant such a conclusion, and does not prejudice the basic working concept of the desirable period of one year of post-thoracoplasty hospitalization. Thirty-nine per cent of the patients remained in the hospital six to twelve months after thoracoplasty, while 39 per cent were hospitalized continuously for thirteen to eighteen months. Only 12 per cent were in the hospital for longer periods, there being 9 patients who were hospitalized from seventeen to thirty-six months after thoracoplasty.

The extent of the disease and the response to therapy is, of course, the basic consideration in recommendations regarding the length of hospitalization. The experience of the past seven years warrants real optimism

toward achieving a goal of therapy in pulmonary tuberculosis wherein more than 95 per cent of patients fully recover and become completely rehabilitated if complications such as empyema do not occur With such a goal in sight the responsibility for providing the facilities of adequate hospitalization for all persons with active pulmonary tuberculosis warrants the most serious consideration To follow the patients with proper rehabilitation measures including educational facilities will properly complement our medical and surgical strides toward eradicating pulmonary tuberculosis The average hospital stay in this group of patients after thoracoplasty was one year

Follow up Data Follow up data are available in 100 per cent of these patients In fact we have follow up data on all of the 274 patients treated by thoracoplasty except for 1 patient Thirty nine other patients were treated by thoracoplasty and are grouped as miscellaneous as they include those on whom only a one-stage three-rib thoracoplasty was performed or a space-closing thoracoplasty procedure for unexpanded pneumothorax was performed and a few who did not have streptomycin.

Other Surgery Other major surgical efforts were carried out in 5 patients Pneumonectomy was performed in 2 a year after thoracoplasty and cavernostomy was performed on 1 patient eight months after thoracoplasty All of these secondary operations were performed on the thoracoplasty side One patient died six months following pneumonectomy and a 3 cm cavity was present in the thoracoplasty collapsed upper lobe from which numerous acid fast bacilli were isolated Autopsy examination revealed miliary tuberculosis of the remaining lung liver spleen and kidneys The other patient treated by pneumonectomy continued to have a positive sputum for eighteen months but has since been negative for two years and the disease is considered inactive A 2 5 cm patent cavity was present in the removed thoracoplasty-collapsed lung Sputum became negative immediately after lobectomy in the 2 patients and has continued negative for approximately two years The patient on whom the cavernostomy was performed has had a negative sputum for four years

It is our policy to recommend excisional surgery usually lobectomy or pneumonectomy if the sputum remains positive for six months following thoracoplasty and if other sources for positive sputum are not identified Other patients in this group who had persistently positive sputum declined recommendations for extirpative surgery Revision thoracoplasty is not practiced in attempts to close cavities which remain patent after thoracoplasty With the steadily increasing utilization of extirpative methods in preference to thoracoplasty secondary operations for so-called surgical failures have rapidly declined Secondary operations are generally technically more difficult of greater magnitude and characterized by poor results The initial surgical effort is the one upon which success is dependent A total surgical effort with highly satisfactory results is now available and an implied or actual reservation of having something else to try if a particular procedure fails certainly increases the patient s insecurity

Complications There were no instances of bronchopleural fistula or empyema following thoracoplasty Nine patients developed pleural fluid

all responded to thoracentesis and it did not delay further operative stages Seven developed atelectasis, and 2 had wound infection Spread of the disease did not occur within three months following thoracoplasty

Results Sputum conversion from positive to permanent negativity occurred immediately, *i e*, within six months after thoracoplasty in 70 per cent of the patients An additional 5 7 per cent converted within twelve months after surgery and remained negative, a total sputum conversion in 53 patients or 75 7 per cent There were no operative deaths, *i e*, death within sixty days of operation Six patients have subsequently died from progression of disease, an overall mortality of 8 5 per cent One other patient was killed but his disease had become inactive In appraising rehabilitation 53, or 75 7 per cent, of the 70 patients are well and working or are able to work Six are hospitalized, 3 of whom have a poor prognosis, and 3 a good prognosis Four patients are alive, 2 have persistently positive sputum and 2 are negative but unable to work

Certain interesting data pertaining to the patients who died due to progression of tuberculosis are noted in Table 18

Table 18. Deaths in Fibrocaseous Tuberculosis Thoracoplasty. 70 Patients

No Deaths	*Survival Post-Tcp (months)*	*Age at Tcp*	*Sex*	*Race*	*Other Surgery Post-Tcp*	*Disease Duration Prior to Tcp (months)*	*Cavitary Disease Side of Tcp*	
							Before Tcp	*At Death*
	19	45	F	W	None	17	Yes	Yes
	36	21	M	W	Closed Pneumonolysis Opposite side	4	Yes	No Autopsy
6	24	39	M	W	None	21	Yes	Yes
	17	24	M	N	Pneumonectomy on Tcp Side	12	Yes	Yes
	41	27	M	W	None	7	Yes	Yes
	48	34	M	W	None	6	Yes	No Autopsy

Appraisal of This Experience and Its Influence on the Surgical Therapy of Pulmonary Tuberculosis In making an appraisal of data upon which one has selected a procedure or surgical method in the therapy of pulmonary tuberculosis, subsequent developments may suggest that some other methods would have been preferable In perusing the indications presented in the 6 patients who died as a result of progression of pulmonary tuberculosis, it seems in retrospect that at the time, 1947-1948, the selection of thoracoplasty was suitable In evaluation of the results it also seems reasonable to again emphasize that failure of conversion of sputum to negative within six months following thoracoplasty is an indication for extirpative surgery The involved lobe or a lung should be surgically removed if no other source for the positive sputum is detected and the patient's general condition permits. In 5 of the 6 deceased patients, the

sputum remained persistently positive eighteen to forty-eight months after thoracoplasty

Extrapleural Thoracoplasty in Caseofibrous Tuberculosis *Characteristics* In the caseofibrous type of pulmonary tuberculosis the fibrous element predominates Roentgenographically the lesions appear as linear areas of increased density usually located in the upper third of the lung fields and cavitation generally forms a part of the disease process sometime during its course The tendency toward encapsulation of the caseous element by the fibrous tissue is considerable and for this reason the aid afforded by collapsing the diseased lung tissue by thoracoplasty is wise and feasible The natural course of the disease is to increase the fibrosis although dissemination of the tubercle bacilli by disease progression hemoptysis and bronchogenic or hematogenous spread are not infrequent developments As these may occur at any time the danger of awaiting disease retrogression far outweighs the risk involved in the earlier application of thoracoplasty or extirpative surgery in this type of disease

This is the most common type of chronic pulmonary tuberculosis and before the introduction of chemotherapy comprised along with the fibrous type of the disease almost the entirety of those patients to whom thoracoplasty was offered However these two groups have comprised only about one-third of the patients on whom thoracoplasty has been selected as the appropriate surgical therapy at Fitzsimons since January 1 1947 Unfortunately the patients are often not seen early as the clinical manifestations of the disease may be few These usually include mild general malaise slight to moderate productive cough sustained low grade fever 99-99 6° F and a very gradual loss of weight all of which may be attributed to a variety of causes which do not suggest a roentgenographic examination of the chest

Indications The indications for thoracoplasty in caseofibrous tuberculosis employed in this group of 72 patients have been simply its advocacy before resistance to chemotherap developed, and in the absence of recognizable contraindications The results obtained from the prolonged use of chemotherapy and the surgical removal of the remaining lesions is steadily surpassing those of thoracopla ty alone.

The major problem is to obtain the general acceptance of the application of surgical therapy as soon as indicated This illu trative case report is a mild dramatization of time loss and low disease progression in an individual manifesting excellent resi tance to the effects of the tubercle bacillus but compelled to accept restriction of activity during a most significant period in the patient life (Fig 35)

Case Report. A white male thirty year of age rev[redacted]
having been hospitalized elsewhere in June 1942, t[redacted]
During the clinical investigation an x-ray examination [redacted]
made sputum wa positive for tubercle bacilli and a [redacted]
cough of several years duration had been present An
thorax on the left wa attempted but wa unsuccessful
phrasu was then accompli hed He was discharged [redacted]
because of active pulmonary tuberculosis and even th[redacted]
hospital again t medical advice

> For the next four and one-half years he worked intermittently at a variety of jobs from laborer to sedentary part time work. Intervals of several months of unemployment were frequent because he did not feel well and often had his employment terminated because of his ineffectiveness. Primary syphilis was diagnosed in 1942 and intravenous arsphenamine given for eight months comprised the specific therapy. No sputum examinations were made during this period of nearly five years, but three or four physical examinations were made without apparently detecting evidence to recommend further study. In April, 1947, he was hospitalized elsewhere because of mild symptoms and for the purpose of an evaluation of the activity of the tuberculosis. His complaints were minimal. Sputum was positive for acid-fast bacilli and he was transferred to Fitzsimons, November 28, 1947. Chest roentgenogram revealed a moderate amount of exudative infiltration bilaterally but especially on the left. Blood Wassermann and Kahn were positive. Bed rest was inaugurated and streptomycin, 1 gram daily beginning January 1, 1948, was followed in one month by thoracoplasty, seven ribs, three stages, which was completed March 15, 1948. The total streptomycin administered was 99 grams. The patient left the hospital against medical advice five weeks after the completion of thoracoplasty. His whereabouts was unknown for about two years but he has since been followed both as an out-patient and for one month hospitalization in August, 1952. The sputum is positive and there is roentgenographic evidence of a 2 cm. cavity in the right lung. He received chemotherapy during this hospital stay and again left against medical advice. The tuberculosis was considered far advanced. Here then is ten years of slow disease progression and all the while he was probably expectorating tubercle bacilli which infected others, but sufficient host resistance was present to mask this progression.

The proper directing of the presently available, splendid facilities makes it much easier to obtain the patient's acceptance of recommended therapy. The physician's responsibility is probably even greater with these added implements, in that a much higher percentage of patients are expected to reach and maintain the phase of inactive disease.

Extirpative surgery is now recommended within a relatively short period after disease detection at the same time that chemotherapy is administered.

Plan and Effect of Chemotherapeutic Agents. Streptomycin and other antibacterial drugs are less effective in the caseofibrous types of tuberculosis than in the caseopneumonic or fibrocaseous types. The reason is simply that there are fewer exudative or new lesions which respond favorably to these drugs. One-half of the patients were operated upon in 1947 and 1948, and streptomycin alone was used during this period. There was a wide variation in the dosage of streptomycin, 18 to 376 grams. Eighteen of the 72 patients noted mild to moderate untoward effects from the drug. Although thoracoplasty, as the preferred surgical procedure, has decreased in usage less rapidly in caseofibrous tuberculosis than it has in some of the other types of disease, only 14 such patients were treated by thoracoplasty alone in 1951 and 1952 as compared to 35 during the years of 1947 and 1948.

Age, Race, Sex, and Known Duration of Disease Prior to Thoracoplasty. The average age in this group was thirty-two years. A comparison of two

age groups namely those eighteen to twenty-one years and those thirty five to forty years was made there were 8 patients in the former and 11 patients in the latter group There was no significant difference in the extent of disease chemotherapy effect or plan of its use duration prior to thoracoplasty or late result *i.e.* work capacity in the two groups Fifteen per cent were Negroes approximately the same as that of the entire group of patients treated by thoracoplasty alone The evaluation of results relative to race is influenced by several variable factors such as length of hospital stay extent of disease patient's attitude and disease duration prior to thoracoplasty If these factors are basically the same there seems to be no appreciable difference in results The Negro patient will be well



FIG 35 —Caseofibrous tuberculosis of long duration. Poorly cooperative patient. Poor results. *A* August 27 1942 Lesions left upper lobe have probably been present for years but produced minimal symptoms and was not previously detected. *B* February 2 1948 Pre-thoracoplasty almost six years after detection of disease. Slow progression has occurred with bilateral involvement.

advised however to adhere strictly to the recommendations of those competent in the surgical treatment of pulmonary tuberculosis In our experience sex has not been an influencing factor in either therapy or results

The duration of the disease process prior to thoracoplasty was variable and somewhat difficult to define In our group of 72 patients 7 had had known disease less than six months and 6 others had a duration of five years or more There was not a marked rise at any period as evidenced by these data duration six to twelve months 28 per cent thirteen to eighteen months 17 per cent nineteen to twenty-four months, 10 per cent twenty-five to thirty-six months 10 per cent and thirty-seven to sixty months 19 per cent

The average duration of disease prior to thoracoplasty based on the finding of acid fast bacilli in the gastric contents or sputum was twenty-three months There was no tangible evidence to suggest that delay in

the application of thoracoplasty was warranted in this group after the maximum resolution of any new exudative elements of the disease had occurred The merits of extirpative methods as opposed to thoracoplasty collapse in the caseofibrous type of tuberculosis with presently available chemotherapy are, I believe, definitely favorable to the former However, if thoracoplasty is selected, its early application is strongly recommended The "spot on the lung" often does not respond favorably to a policy of watchful waiting, its diagnosis and treatment are urgent requirements (Fig 36)

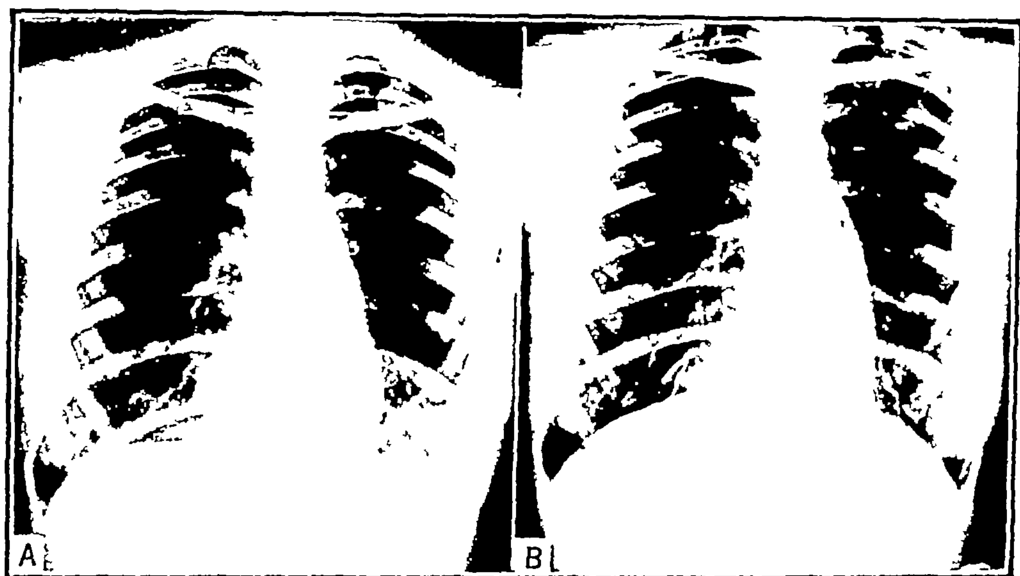


FIG 36 —Caseofibrous tuberculosis treated by thoracoplasty and chemotherapy *A* February 10, 1943 A 29-year-old white female A "spot on the lung" watched four years without a positive diagnosis *Surgical exploration and removal of the questionable lesion for diagnosis is far less dangerous than awaiting developments* *B* July 2, 1947 Large cavity left upper lobe Sputum positive for tubercle bacilli Treatment consisted of bed rest, 18 months, 68 grams of streptomycin, and a seven-rib, three-stage, thoracoplasty during November and December of 1947 Discharged from hospital January, 1949 She has remained well, has had two children since discharge, and cares for all phases of her household duties

Extent of Disease According to the National Tuberculosis Association Standards, the extent of tuberculous disease in this group of 72 patients is as follows far advanced, 46, moderately advanced, 22, and minimal, 4 The categorizing of the extent of disease in patients treated by thoracoplasty is largely dependent upon roentgenographic interpretation, and although generally satisfactory is far less exact than the evidence afforded by the examination of the surgically excised tissue plus the surgeon's evaluation of the extent of disease which was not removed The disease process as now treated by surgical, extirpative measures, other than pneumonectomy, seems to be definitely less extensive than that treated by thoracoplasty prior to the chemotherapeutic era and during the first two years of that era It is not ineffectiveness on the part of thoracoplasty

which makes it give way to extirpative surgical methods in 80 to 90 per cent of uncomplicated case problems. It is the avoidance of thoracic deformity following extensive thoracoplasty and the fact that the disease process usually responds to chemotherapy so that it is more localized in extent which makes extirpative surgery preferable.

Cavitation. Ten of the 72 patients did not have roentgenographic evidence of cavitation in the operated lung noted during the course of the disease. Single cavity size of 5 cm. or more is grouped in the giant cavity category. Fifteen patients had a single cavity of 4 cm. in diameter in the more involved lung, 11 had a 3 cm. cavity, and in the remaining 30 the size was 2 cm. or less. In 8 there was bilateral cavitation.

Endobronchial Disease. Fifty-eight of the 72 patients were examined bronchoscopically. There was no selecting in this group and preferably all patients undergoing surgery should be so examined preoperatively. Of those examined, 22 per cent had evidence of endobronchial disease. The response to chemotherapy was excellent and surgery was deferred until this response was evidenced bronchoscopically.

Length of Hospitalization. Patients classified as having a caseofibrous type of tuberculosis are, in general, representative of those who have had protracted disease often unnoted for months or years. Symptoms resulting in their being hospitalized are often of such mildness that the hospital stay is apt to be short and frequently repeated. There is a hesitancy on the part of the physician to recommend surgery and as a result the patients often go for months or years neither clearly ill nor well. The designation of hospital stay for the 72 patients under consideration is the continuous period before and after thoracoplasty, which is frequently not the total (Table 19). A period of six months' hospitalization following thoracoplasty seemed to provide in the vast majority as good a result as longer periods of post-thoracoplasty hospitalization.

Table 19. Caseofibrous Tuberculosis Treated by Thoracoplasty and Chemotherapy. Length of Hospitalization. 72 Patients

Months	*Before Thoracoplasty No. Patients*	*After Thoracoplasty No. Patients*
Less than 6	22	11
6–12	30	27
13–18	10	24
19–36	7	5
36+	3	0
		5 (Hospitalized)

Follow-up Data. Information concerning the post-thoracoplasty status of these patients is present in all of the 72 patients.

Other Surgery. Artificial pneumothorax therapy, either unilateral or bilateral, was carried out for three or more months in 14 patients. Three had closed intrapleural pneumonolysis performed, 1 a lobectomy several months after thoracoplasty, and 1 had a lucite plombage on the less in-

volved side. It is very doubtful if any of the temporary collapse therapy measures are now of sufficient benefit to warrant their use prior to thoracoplasty in this type of disease, and they have been almost abandoned.

Complications. The spread of tuberculosis following surgery is often not easily ascertained. Almost without exception our patients have received penicillin in large doses, two to three days before surgery and for ten to fourteen days after surgery in addition to streptomycin. The transient presence of a roentgenographically noted parenchymal infiltration which clears within a week without recurrence, together with the disappearance of any accompanying symptoms, has not been considered as evidence of spread or reactivation of the disease. In this group of 72 patients, 3 had a spread to the contralateral lung twelve and twenty-seven months after surgery. In all 3 instances, there was roentgenographic evidence of cavitary disease beneath the thoracoplasty, and the patient had earlier declined the recommendation of extirpative surgery for thoracoplasty failure. Pleural effusion required thoracenteses in 5 patients. One patient had a massive atelectasis requiring bronchoscopic aspiration of bronchial secretion on the third postoperative day. One patient suffered a severe transfusion reaction from which he made a complete recovery. None developed bronchopleural fistula or empyema.

Results. Two criteria for estimating results have been used: first, the conversion of a positive to negative sputum which remains negative, and second, the capacity of the patient to work. This includes a wide variety of gainful occupations, many of a sedentary nature but often hard manual work, regularly attending school, and the performance of the normal duties of a housewife. The results on this basis were as follows. Sputum conversion early, *i.e.*, within six months or less following thoracoplasty, occurred in 49 patients, or 68 per cent, and late conversion in another 14 per cent, totaling 82 per cent sputum conversion. Fifty-six, or 78 per cent, are well and working, 3 others are well of their tuberculosis but unable to work for other reasons. Of the remaining patients, 10 continue to have positive sputum and 3 are dead. Sputum conversion within one year or less means almost without exception that the patient will be completely rehabilitated and able to return to work.

Review of Deaths. There were no operative deaths. Three patients, ages forty-three, fifty, and fifty-six years, whose known duration of disease prior to thoracoplasty was eighteen, thirty-five and nineteen months respectively, died and their deaths occurred ten, forty-three, and fifty-two months after thoracoplasty. In 1 of these patients, age fifty-six years, death was due to coronary occlusion fifty-two months after thoracoplasty. There was no evidence of active tuberculosis as determined by necropsy, and his sputum had been negative since operation. The fifty-year-old patient left the hospital fifteen months after thoracoplasty; his sputum has been consistently positive since operation. The known duration of disease was thirty-five months prior to surgery and unfortunately he had become a chronic alcoholic. Post-thoracoplasty roentgenographic examinations showed a 3 cm. cavity beneath the thoracoplasty for two years prior to his death. Extirpative surgery should probably have been advised. A necropsy was not obtained. The third patient exhibited considerable

evidence of an initial exudative process with a few symptoms and favorable response to streptomycin. Cavitation developed and thoracoplasty was advised Sputum conversion was not accomplished after eight months and lobectomy was advised but declined by the patient He left the hospital against medical advice at this time and three months later died elsewhere Necropsy was not performed Information obtained from the hospital where he died indicates that the cause of death was pneumonia probably of tuberculous origin This adds emphasis to the advisability of extirpative surgery when it is evident that thoracoplasty has not resulted in conversion of the sputum

Appraisal of This Experience and Its Influence on the Surgical Therapy of Pulmonary Tuberculosis This is the type of pulmonary tuberculosis which has long been treated by thoracoplasty with reasonably satisfactory results The results achieved here attest to the effectiveness of thoracoplasty However with the present availability and effectiveness of the chemotherapeutic agents it is my opinion that the indications for a seven or more rib thoracoplasty alone are few and are limited to the treatment of empyema or those patients with involvement of one entire lung a good contralateral lung and on whom pneumonectomy though recommended is declined

Extrapleural Thoracoplasty in Giant Cavitation. *Definition* The designation of giant cavitation preoperatively is based solely on the roentgenographic evidence of at least one pulmonary cavity 5 or more centimeters in diameter The underlying disease process may be classified as caseopneumonic, fibrocaseous caseofibrous or fibrous The large size of the cavity significantly increases the difficulties of obtaining desirable results and places the disease process in a far advanced category From January 1 1947 through June 30 1953 65 patients have been treated surgically for giant cavitary disease There has been a steady decrease in the incidence of such large excavations since 1950 which may reflect the benefit of chemotherapy Thoracoplasty was the procedure initially selected in 38, and extirpative procedures in 27 A combination of both is now considered the preferable surgical method of management

Extent of Disease Among the thoracoplasty treated patients more than one giant cavity was present on the same side in approximately 10 per cent and 97 per cent had bilateral parenchymal involvement The extent of disease on the less involved side was greater than minimal in one half of the latter group Cavities 2 to 4 cm in diameter were present in the better lung in one-fifth of the patients while one-half had at least one cavity in the more involved lung of a diameter greater than 5 centimeters The presence of giant cavitation is in itself probably an indication that the host possesses some ill-defined qualities referred to as resistance This feature is emphasized by noting that three-fourths of those patients with giant cavitation who were treated by thoracoplasty were classified as having a caseofibrous or fibrous type of tuberculosis Only one-fourth were caseopneumonic or fibrocaseous

Effect of Chemotherapeutic Agents These agents exert no particular influence in giant cavitary disease differing from their behavior in other varieties of pulmonary tuberculosis The large area of lung destruction

and the altered blood supply may decrease the concentration of these agents reaching such lesions The massive quantity of tubercle bacilli present is a challenge to the effectiveness of any medicament We have not made any alteration in our regimen for chemotherapy on the grounds of the presence of giant cavitation I believe, however, that an improved surgical approach may indicate that a larger dose of the chemotherapeutic agents is desirable Combined intermittent therapy is advised, administering 2 grams of streptomycin three times a week, and 300 mg isoniazid and 12 grams para-aminosalicylic acid daily for a preoperative period of two to three months, this should be followed by a two-stage, five-rib thoracoplasty, and extirpative surgery, usually a lobectomy, one to three months after thoracoplasty Chemotherapy should continue for a total of twelve to twenty-four months The total dosage of streptomycin over a one year period under such a plan would be approximately 300 grams The dosage of streptomycin alone in this group of patients with giant cavitary disease varied from less than 100 to more than 500 grams Nine patients manifested untoward side effects exclusive of eighth nerve disturbances, and 4 of these had received more than 300 grams of streptomycin The dosages and regimens are indicated in Table 20

Table 20. Streptomycin Therapy in Giant Cavitary Disease Treated by Thoracoplasty. 38 Patients*

Dosage		*Combined with Other Drugs*	*Toxic Symptoms*
Grams	*No Patients*	*No Patients*	*No Patients*
-100	2		
100-199	19		
200-299	8	14	9
300-399	5		
400-499	1		
500+	2		

Regimen	
1-2 Grams Daily	*Other Regimens*
No Patients	*No Patients*
30	8

* One patient is still hospitalized

Age, Race, Sex, and Known Duration of Disease Prior to Thoracoplasty One of every 5 patients was twenty-one years of age or younger Almost one-half were twenty-two to thirty-four years, 1 of every 6 was between thirty-five and fifty-nine years, while 5 were fifty-one years or older The average age was thirty-two years Four out of 5 were white, the remainder Negroes Seventy-six per cent were males Four patients had a known disease duration of six months or less prior to thoracoplasty In this group certain data are of interest which emphasizes the favorable factors of youth and surgical therapy early during the course of the disease, together with streptomycin preparation and protection (Fig 37).

A comparison with 9 patients whose known duration was seventy two or more months averaging one hundred and seven is striking The extent of recognizable cavitary disease was similar in both groups The degree of impairment of pulmonary function was not determined by bronchospirometric methods. However the evidence of extensive pulmonary fibrosis and emphysema indicated considerable decrease in function The

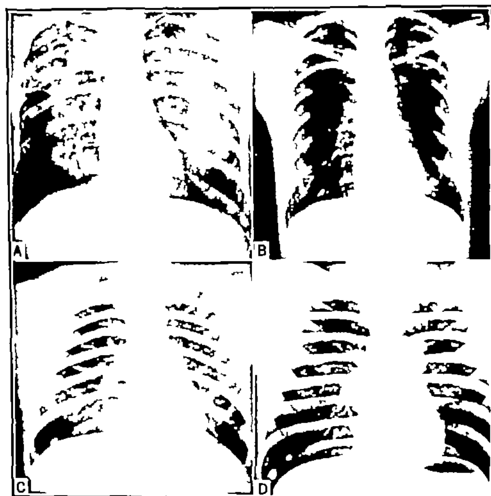


FIG. 37 —Pre-thoracoplasty chest roentgenograms of four patients demonstrating giant cavitation. Ages 21 23 and 33, whose known duration of disease prior to thoracoplasty was three and four month All had less than 200 grams of streptomycin, and in three no other drug wa administered. Only one had any untoward manifestations due to chemotherapy The period of hospitalization after thoracoplasty wa 10 15 18, and 20 month All are alive and well, three are working 40 hours per week and one 20 hours per week

ages of these patients were eighteen twenty-one thirty five thirty six thirty nine forty-seven fifty and fifty four years The post-thoracoplasty period of hospitalization was in excess of twelve months in all except 2 patients and averaged eighteen months Only 3 are well and working or able to work.

The efforts directed toward surgery relatively early in the course of tuberculosis were not fruitful prior to the antibiotic era In 1925 Alexander wrote, "From many experienced surgeons and phthisiologists comes the plea for earlier operation for those patients who have not continued to benefit from a sanatorium regimen, and especially for those who are not making satisfactory improvement with artificial pneumothorax that is incomplete because of pleural adhesions "[1] More than twenty years later DuFault reported the experience at Rutland State Sanatorium during the twenty-year period 1927 to 1947 He wrote concerning the indications for thoracoplasty in pulmonary tuberculosis, "The clinical indications have changed very little if at all throughout the whole period "[4] Alexander emphasized that thoracoplasty should be performed, "without regard to the age of the lesions, as soon as the indications are clear Not only does a properly indicated thoracoplasty bring about complete healing of a greater proportion of young than old lesions, but it protects patients with young lesions from serious extension of the disease and other complications that might make an intended later thoracoplasty impossible In occasional cases the indications for thoracoplasty are clear within a year of the onset of the disease, and more frequently during the second year Incidental benefits of early rather than late operation are the psychic, social, and economic advantages of bringing about arrest of the tuberculosis as soon after its onset as possible "[2] At that time he thought the great majority of patients on whom he had performed thoracoplasty had lesions which were between two and eight years old The average duration of the disease in our patients with giant cavitary disease, excluding those longer than seventy-two months, was nineteen months The average for all in the group was forty months In the fibrocaseous group of seventy patients it was fourteen months, while twenty-three months was the average in the caseofibrous group The average period of continuous hospitalization prior to thoracoplasty in the group of giant cavitary disease was twelve months, and the average length of hospital stay after thoracoplasty was eighteen months

Between the two extremes of early surgery, *i e*, within six months from onset, and delayed surgery, *i e*, after six years of known disease, are two-thirds of the patients treated by thoracoplasty for giant cavitation Four male patients were classified initially as of the caseopneumonic type, and they present certain interesting features The streptomycin dosage varied from 200 to 500 grams Two had single cavitation on the more involved side of 8 cm or more The duration of disease prior to thoracoplasty was seven, nine, and twelve months These patients were young, being twenty-three, twenty-four, twenty-eight, and twenty-nine years of age Three were Negroes, 1 of whom had a 4 cm cavity on the least involved side and is now dead Two are well, 1 has been regularly attending school forty hours per week for the past three years, and the other patient is not working My observation is that with judicious chemotherapy, Negroes respond equally as well as others to the surgical treatment of pulmonary tuberculosis The only white patient in the caseopneumonic group is well and has been working regularly forty hours per week as a stock clerk in a supermarket since two years after thoracoplasty

The predominant type of disease in this group treated by thoracoplasty was caseofibrous Twenty-one are in this group Six had a single cavity on the operated side of 8 or more centimeters in diameter Two of these are dead and of the surviving 4 only 1 has had a consistently negative sputum since thoracoplasty None is able to work. Of the remaining 15 only 1 is dead while 8 are well and working regularly 40 hours a week attending school on a full time basis or doing the usual duties of a housewife Again those who reached this inactive disease state are young adults twenty-one to thirty four years of age and the duration of the disease prior to surgery was usually less than twenty four months The remaining 7 patients are alive have continued to have positive sputum, and are not well

Cavitation The fate of patients having single cavitation of 8 or more centimeters in diameter is very poor There were 6 such patients who did not fall in the category of early thoracoplasty the delayed thoracoplasty group or in the caseopneumonic classification All were operated upon in 1947 and followed until death or more than five years after thoracoplasty Two are dead 1 of whom was fifty four years of age and died within three months after thoracoplasty The other was thirty-one years of age and died of disease progression four years after surgery One of the 4 surviving patients has had a consistently negative sputum since operation all the others are positive None are able to work The over all results of thoracoplasty for giant cavitation are noted below

Endobronchial Tuberculosis Of 27 unselected patients who had bronchoscopic examination 37 per cent had demonstrable endobronchial involvement The beneficial effects of chemotherapy on this phase of the disease process are marked However the constant disease focus of a giant cavity is urgent reason for attacking the source of positive sputum bathing the bronchi Therefore early thoracoplasty and extirpative surgery applied a few months after identifying the nature of the cavitary disease and providing adequate chemotherapeutic preparation and protection in a suitable surgical candidate is recommended

Length of Hospitalization The length of continuous hospitalization before and after surgery is in itself of only relative value The significant factors are the nature and extent of the disease process the clinical course of the disease and the patient s cooperation in carrying out proper recommendations regarding therapy The category of giant cavitation presents many variables however it probably permits evaluating the benefits of hospital stay better than most other types of the disease An initial observation would suggest that these patients are generally so ill that hospitalization would be mandatory Interesting is the fact that in 18 per cent of these patients a chest roentgenogram performed as a routine examination such as separation from the military services reenlistment annual physical examination mass survey by *x*-ray examination of the chest etc in individuals who did not consider themselves ill revealed the evidence which led to the diagnosis of pulmonary tuberculosis Lower figures are noted only in the group classified as caseopneumonic or empyema Twenty-one per cent of the patients in the giant cavitary group had a family history of exposure to pulmonary tuberculosis This is second

only to the empyema group, in which a positive family history was noted in 23 per cent The average length of continuous hospitalization before and after surgery was higher in this group of patients than in any other category thirty months Periods of short hospitalization before or after thoracoplasty are not included in these data

Other Surgery In the development of surgical concepts in the antibiotic era thoracoplasty has often held the place of a preliminary operation, with the thought that if the sputum did not become negative in six to twelve months, extirpative surgery would be considered This plan, however, was not rigidly accomplished in patients with giant cavitation as only 2 patients had extirpative surgery performed after the failure of thoracoplasty to convert the sputum to negative In 1 patient a pneumonectomy on the thoracoplasty side was performed and the patient is well but not working Another patient has continued to have positive sputum after an upper lobectomy and segmental resection of the dorsal division of the lower lobe on the thoracoplasty side In retrospect, and after further experience with extirpative surgical effects, I am convinced that the giant cavitary disease problem is best met by chemotherapy and thoracoplasty, five or seven ribs, followed in two to three months by lobectomy or pneumonectomy Chemotherapy should *continue for a total of twelve to eighteen* months The use of cavernostomy by catheter drainage (Monaldi) prior to thoracoplasty has found favor in several thoracic surgical clinics[11,17] I have not, however, advocated this procedure or external cavernostomy, and in only 1 instance was Monaldi drainage carried out in this group of patients Pneumoperitoneum was often employed, and artificial pneumothorax was occasionally induced on the side of the more involved lung Their value, which is doubtful, is as an aid in preparation for surgery Two other patients with giant cavities following thoracoplasty performed elsewhere, are not included here

Complications No patient developed a bronchopleural fistula or empyema following thoracoplasty The subclavian vein was lacerated and immediately sutured in 1 patient In 118 thoracoplasty procedures, wound infection occurred 3 times and the pleura was accidentally opened 3 times This accident occurred more often at the second and third stages In the teaching of operative technique the resident does not undertake the upper phase first stage thoracoplasty until he has repeatedly performed the second and third stages of this operation This may account for the more frequent injury to the pleura at these later operative stages There were no spreads of the disease within three months after surgery In 3 instances spread was evidenced in 4, twenty-one and forty-eight months after thoracoplasty This again suggests that at the present time extirpative surgery should, if the patient's condition warrants, be accomplished within a few months after thoracoplasty failure, or, if the contralateral disease process permits, thoracoplasty is performed as a preliminary to extirpative surgery Spread occurs far more often before than after surgery Ten of the 40 patients exhibited spread of their disease prior to thoracoplasty

Results Recovery, arrest, or inactivation in the giant cavitary tuberculous disease process, exclusive of the large cavity which is lost to view or decreases rapidly in size in a few weeks after it is noted, is a triumph

for the patient and his doctors. Follow-up data are characteristically easiest obtained concerning patients whose prognosis is the poorest and whose need for hospitalization is the greatest The giant cavitary disease problem meets these requirements. Briefly one-third of these patients had multiple cavitation in addition to one cavity of 5 cm in diameter in the more involved of the two lungs Thirty-seven per cent of the 27 unselected patients examined bronchoscopically had evidence of endobronchial disease Streptomycin sensitivity studies vealed that even though the dosage of the drug was often large and in a out two-thirds of the cases was not combined with any other drug in 24 patients on whom these studies were made 45 per cent were sensitive to the drug at the time thoracoplasty was started One-fourth of the p tients had mild to moderate untoward reaction from streptomycin. The average age was thirty two years average onset to thoracoplasty was forty months the average length of continuous hospitalization was thirty months and in 18 per cent the disease even though extensive was detected as the result of a routine chest roentgenogram of an individual who presumably was well Thirty-four of the 38 patients are at least two years post-surgery Six are dead 1 as a result of non tuberculous disease but all had active lesions at the time of death Fifty per cent are working or able to work part or full time Only 2 had extirpative surgery following thoracoplasty failure a low percentage but the patient s poor condition often precluded other surgery In considering the entire group of 38 patients 21 or 55 per cent have converted their sputum from positive to negative within one year following thoracoplasty The encouraging element is the decreasing number of patients encountered with the large destructive lesions Our experience with extirpative surgery in the treatment of giant cavitation has been very satisfactory and its use plus thoracoplasty collapse of the chest wall is the preferable method of management.

Extrapleural Thoracoplasty in Fibrous Tuberculosis. *Characteristics* Fibrous pulmonary tuberculosis is characterized by a long disease history extensive fibrosis of the involved lung contraction of the disease tissue and thorax and poor response to the chemotherapeutic agents It represents the residual or survivals of a much larger number of persons who lost the challenge of recovery from pulmonary tuberculosis. The disease process may be so insidious in its clinical manifestations as to go undetected for years The annual chest roentgenographic examination if universally applied would eliminate this failure of disease detection and the recent advances in the treatment of pulmonary tuberculosis have decreased the frequency with which this type of disease process is encountered Prior to the chemotherapy era fibrous tuberculosis probably accounted for a considerable majority of patients on whom thoracoplasty was performed During the period 1947–1952 only 29 patients classified as fibrous tuberculosis were treated at Fitzsimons Army Hospital by extrapleural thoracoplasty and 82 per cent of these were so treated prior to 1950 The mildness of the clinical course is emphasized in noting that in 9 of the 29 patients included in this series the disease was first detected on routine roentgenographic examination of the chest In only 7 patients was there a history of known contact with active pulmonary tuberculosis Chronic fibroid

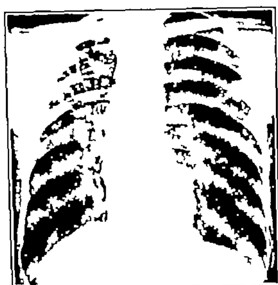
tuberculosis represents the older tuberculous patient who has demonstrated a sustained and high degree of resistance to tuberculous infection but insufficient to permit healing without a price which is usually that of associated changes of emphysema, pulmonary fibrosis, and cardiac damage (Figs. 38 and 39)

Indications The contraction of the diseased lung and thoracic cage on the involved side in predominantly unilateral fibrous tuberculosis was early recognized as a feasible indication for thoracoplasty The surgical



FIG 38 —Chronic fibrous tuberculosis treated by thoracoplasty and chemotherapy *A* September 1, 1949 White, age 56 years Disease duration 30 years prior to thoracoplasty Patient is well and retired Streptomycin, 141 grams *B* January 9, 1948 White, age 34 years Disease duration prior to thoracoplasty, 110 months Thoracoplasty, four stages, nine ribs, performed February-April, 1948 Streptomycin, 127 grams *C* Same patient as *B* One year post-thoracoplasty, left Patient is well and has been working 10 hours a week since two years after thoracoplasty.

effort serves to further aid and magnify the natural healing tendency evidenced by decreasing the volume of the diseased lung. The characteristics of fibrous tuberculosis were for many years the usual requirements which met the indications for thoracoplasty. The clinical case material available during this early period was the desperately ill patient with long-standing pulmonary tuberculosis. Often there was clinical evidence of involvement of other organs, especially the larynx and gastrointestinal tract, as well as amyloid disease. It is thus easy to understand the surgical mortality of 20 per cent for thoracoplasty at our hospital prior to 1931.



A



B

Fig 30.—Chronic fibrous tuberculosis treated by thoracoplasty and chemotherapy. *A* October 28, 1947. White, age 50 years. Disease duration prior to thoracoplasty 72 months. Three-stage thoracoplasty March-April 1948. Sputum still positive. *B* March 17, 1948. White, age 51 years. Disease duration prior to thoracoplasty 168 months. Thoracoplasty four stages, six ribs May-July 1948. Pulmonary function and clinical condition much improved but sputum still positive.

Since the advent of chemotherapy the indications for thoracoplasty in fibroid tuberculosis have not appreciably changed. However, with the beneficial effects of chemotherapy, early disease detection and the wide application of extirpative surgery, there is little reason for the cooperative tuberculosis patient to become the chronic far advanced fibrous type.

Effect of Chemotherapeutic Agents. The beneficial effects of the chemotherapeutic agents in fibrous pulmonary tuberculosis are chiefly symptomatic. They aid in the reduction of sputum, improve the appetite and aid in the healing of endobronchial tuberculous lesions. They seem to have very little effect on the established fibrous lesions, cavitary or non cavitary. As is often the case there are new lesions associated with the old fibrous elements and chemotherapy has the usual beneficial results in the resolution of these newer lesions.

Twenty of these patients were treated by streptomycin alone and prior to the combination of this drug with other agents Of the 29 patients, 11 received less than 100 grams of streptomycin, 12 received 100 to 199 grams, 3 received 200 to 299 grams, and 3 received more than 300 grams Twenty-two patients received streptomycin for six months or less In light of our present experience and knowledge concerning chemotherapy and its effect in fibrous tuberculosis the dosage was, in most instances, excessive

Age, Race, and Sex Fibrous pulmonary tuberculosis characteristically is noted in the older age group The average age of the patients in this group was forty years as compared to thirty for all thoracoplasty patients There were no patients under twenty-one years of age, 24 per cent were between twenty-one and thirty years, 21 per cent between thirty-one and forty years, 34 per cent were forty-one to forty-nine years, and 21 per cent were over fifty years of age Ninety-seven per cent were Caucasians and 3 per cent were Negroes Seventy-nine per cent were males Of special significance is the fact that the average duration of disease prior to thoracoplasty was one hundred and eighteen months In general, the older the patient the poorer the result Likewise, the prolonged duration does not favorably influence results Only 2 of the 29 patients had a disease duration of less than thirty-two months

Extent of Disease The disease was far advanced in 90 per cent and moderately advanced in the remainder

Cavitation Cavitation in fibrous tuberculosis is almost always present in patients treated by thoracoplasty or extirpative surgery, and only 1 patient in this group did not show roentgenographic evidence of cavitation at the time of surgery or during the observed course of the disease Cavitary size varied considerably from 1 to 4 cm , with the majority being larger than 2 cm Multiple cavitation was present on the operated side in 1 out of every 5 patients Cavitary disease clinically and roentgenographically was characterized by thick fibrous walls and was of long duration Extensive thoracoplasty is required to collapse their walls For this reason extirpative surgery is often preferable On the other hand, the slow but constant tendency toward contraction of the diseased area is often favorably influenced by thoracoplasty

Endobronchial Tuberculosis Twenty-three of the 29 patients were bronchoscoped and 26 per cent had demonstrable evidence of endobronchial tuberculosis This was favorably influenced by streptomycin therapy prior to thoracoplasty

Length of Hospitalization The individual who is ill with fibrous tuberculosis usually has had varying periods of hospitalization prior to the time thoracoplasty is accomplished For this study only the period of continuous hospitalization before and after thoracoplasty is considered The average length of hospitalization was twenty-four months, eleven months before and thirteen months after thoracoplasty, the whole period varying from six to seventy-four months It is in this group of patients that the period of hospitalization may be appreciably reduced if facilities are available in the patient's home for proper care after operation, and if the sputum is consistently negative These patients are usually thoroughly acquainted with the proper methods of rest therapy, and if purposeful in their efforts,

are able to carry out the prescribed rest measures at home Those patients requiring protracted post surgical hospitalization i e more than one year usually have evidence of tuberculous disease in other organs or other diseases principally cardiovascular in nature

Follow-up Data Follow up data are complete in all patients in this group

Other Surgery None of the patients in this group has had subsequent extirpative surgery on the thoracoplasty side

Complications There were few complications encountered in the surgery and postoperative phases None developed bronchopleural fistulas or empyema Two patients developed wound infections Atelectasis occurred in only 1 patient requiring bronchoscopic aspiration of secretions Two patients required thoracentesis One patient suffered a cerebrovascular accident and hemiplegia

Pulmonary Function The patients with fibroid tuberculosis require careful consideration regarding pulmonary function before any surgical therapeutic efforts are initiated

Results Sputum conversion from positive to negative occurred within one year or less after thoracoplasty in 76 per cent of the patients There was 1 death within sixty days after thoracoplasty 1 died due to progression of the disease another died as a result of coronary thrombosis and 2 patients are still hospitalized both having positive sputum Of the 25 patients who are more than two years postoperative 19 are well and working or able to work, 3 are dead 1 is not able to work and 2 are still hospitalized This over-all result of 76 per cent is excellent Of the 29 patients 22 are well and working 2 others are well of tuberculosis but unable to work because of heart disease and hemiplegia Three patients are dead and 2 have positive sputum and are hospitalized These results however fail to take into account the long period of disease and its associated debility as well as the expectoration of positive sputum with the resultant infection of others Further many patients die of disease progression never reaching the stage of fibrous tuberculosis Therefore the earlier application of surgery is recommended

Appraisal of This Experience and Its Influence on Surgical Therapy Thoracoplasty in the treatment of chronic fibroid tuberculosis is firmly established as an effective method of therapy Effective chemotherapy and the earlier application of appropriate extirpative surgery markedly lessen the number of patients who develop the chronic destructive changes of fibroid tuberculosis The modern therapy of pulmonary tuberculosis is reaping tremendous benefits by achieving early inactivation of the disease process, preventing prolonged disability and enabling the patient so treated to carry on normal activities with minimal danger of disease reactivation

Extrapleural Thoracoplasty in the Treatment of Empyema *General* Thirty patients have been treated by thoracoplasty and chemotherapy for tuberculous empyema 29 had far advanced disease and in 1 the disease was moderately advanced There are several interesting facts concerning this experience In 11 instances artificial pneumothorax therapy was present on the same side on which the empyema developed A contralateral artificial pneumothorax was present in 4 cases In only 1 instance was em

pyema preceded by closed intrapleural pneumonolysis Roentgenographic evidence of bilateral involvement was present in 83 per cent of the patients, while parenchymal cavitation was present on the side in which the empyema developed in 28 of the 30 patients Twelve patients had a mixed infection empyema with evidence of a bronchopleural fistula In 4 of these patients a spontaneous pneumothorax had occurred Spread of the disease to the opposite lung was evident in 5 patients preoperatively, and in one patient spread following thoracoplasty occurred Sixteen of the 30 patients are well, working, or able to work

Age, Race, and Sex The age incidence indicates that 60 per cent were less than thirty-one years of age, and 6 of the 30 patients were less than twenty-one years of age Twenty-seven were males, 25 were Caucasians, 4 were Negroes, and there was 1 Asian The results in the 18 patients under thirty-one years of age indicate that 10 are well and working while none of 5 patients over forty years of age reached this goal of disease arrest

Duration of Disease Prior to Thoracoplasty The known duration of disease was generally prolonged, only 1 of every 6 patients had a disease duration of less than six months, while 1 of every 3 had a duration of more than thirty-one months The average for the entire group was thirty-seven months

Principles of Surgical Management and Chemotherapy Chemotherapy as streptomycin alone or in combination with other agents has been highly beneficial in the treatment both of the empyema and the underlying diseased lung Its use both systemically and locally in the pleural space has been regularly employed In the presence of tuberculous empyema without evidence of a superimposed infection due to pyogenic microorganisms, *i e*, the so-called pure tuberculous empyema, chemotherapy is a significant part of the local therapy Thoracentesis at intervals of a few days, and the instillation of 1 to 2 grams of streptomycin into the pleural space has been regularly practiced As the empyema fluid, with a specific gravity of 1 018 or more, decreases in quantity, thoracentesis is performed less frequently If the lung reexpands the immediate goal of therapy, *i e*, obliteration of the pleural space, is achieved Therapy directed toward the parenchymal disease includes bed rest, and systemic chemotherapy, and a collapse therapy measure such as thoracoplasty or extirpative surgery may be applied after lung reexpansion If the lung does not reexpand after a reasonable period, these latter measures, including decortication, are evaluated as to their applicability

Thoracoplasty is directed toward accomplishing two objectives first, the obliteration of the pleural space, and second, the collapse of underlying parenchymal cavitary or non-cavitary disease This requires removal of all of the upper three to five ribs and usually long segments of the lower ribs, often including the tenth and eleventh ribs, and is carried out in three or four stages Thoracentesis with the removal of all fluid, and local instillation into the pleural space of streptomycin frequently alternating with other agents such as terramycin and penicillin, is carried out regularly at two- to three-day intervals preceding and during the period of the thoracoplasty operations Occasionally there remains a small pleural space in the lower part of the chest which is *not obliterated* It is often

necessary to unroof this space by removal of the overlying ribs. Their removal should extend 2 inches beyond the borders of the unobliterated space. The thickened parietal pleura should be removed, the intercostal structures retained, the skin preserved and its edges folded inward covering the intercostal structures and sutured to the cut edges of the parietal pleura. After an interval of several weeks or months and if the exposed empyema space becomes obliterated, it is desirable to release the folded skin margins, preserve available intercostal structures and close the skin over the exposed area. If the empyema space does not obliterate it is often feasible to attempt its obliteration in the manner just described by using the intercostal muscles and other available chest wall muscular structures to fill the space, releasing the edges and suturing the skin. Pressure dressings are maintained until healing is complete. Several rubber tissue drains should be placed beneath the skin, remaining for four to six days. It is important to remove initially the thickened parietal pleura well beyond the borders of the empyema cavity which is not obliterated by thoracoplasty. This is the problem of tuberculous empyema in which superimposed pyogenic infection has not occurred. It is usually associated with an unexpanded therapeutic pneumothorax or a pleural effusion which does not resolve. Careful investigation of the presence of any unobliterated area, particularly a narrow tract leading to the apex of the thorax, is mandatory before closure of the chest wall defect. The presence of any such dead space leaves an area for the development of an empyema.

If a superimposed pyogenic infection is present, the principles of surgical therapy are altered. The pyogenic infection occurs generally as a result of a bronchopleural fistula. The establishment of external drainage by rib resection or intercostal tube drainage of a pure tuberculous empyema is often followed by a mixed infection empyema. The altered principles of surgical management in established mixed infection are to provide a vent for the escape of air trapped within the pleural space and the closure of the bronchopleural fistula. A vent may be accomplished by the insertion of either a large bore needle or a urethral catheter intercostally, preferably in the second intercostal space anteriorly. The development of a bronchopleural fistula is often a sudden and dramatic incident requiring urgent attention. In instances of a less sudden nature the determination of a bronchopleural fistula in the presence of a pneumothorax or pleural effusion or both may be difficult. The injection of 2 to 3 cc. of a dye such as methylene blue into the pleural space following the withdrawal of fluid and noting whether or not the blue color appears in the sputum may be helpful. Noting changes in the intrapleural pressure following the removal of fluid or air is another aid. If the pressure rises from a negative to a substantial positive reading after the patient coughs, the presence of a bronchopleural fistula is suggested. The character of the pleural fluid is often appreciably altered by the use of the antibiotics and the culturing of pyogenic microorganisms may not be possible. If cultured, the evidence of a mixed infection is confirmed. Occasionally the fistula closes in a matter of hours or a few days. More often, however, the temporary measures of a needle or intercostal tube are inadequate.

In the presence of mixed infection tuberculous empyema and a persistent bronchopleural fistula which remains open, it is necessary to establish external drainage This is accomplished preferably by intercostal tube drainage, inserting a 45 F catheter and connecting it with a water seal apparatus Suction at a pressure of 20 cm of water is usually applied to the catheter Thoracoplasty is seldom indicated early, *i e*, within a few days following the sudden appearance of a bronchopleural fistula Preferably it is accomplished usually four to twelve weeks later During this interval the general condition of the patient usually improves, and chemotherapy, adequate drainage, and a diet high in protein and vitamins is encouraged Reexpansion of the lung may occur, obliterating the empyema space If this fortunate turn of events takes place, the therapeutic efforts are directed toward the management of the parenchymal disease Thoracoplasty as described above is carried out to obliterate the empyema space if the lung does not reexpand, and is, of course, feasible therapy for the parenchymal involvement A small residual empyema cavity at the lower portion of the thorax is not closed until the bronchopleural fistula has been closed for at least several weeks Our efforts directed toward the surgical closure of bronchopleural fistula in mixed infection tuberculous empyema has not been encouraging The use of muscle tissue to fill the opening of the fistula has been the most effective method With adequate drainage the fistula usually closes without attempts at plastic repair We have not recommended the attempted closure of the fistula early, *i e*, within a few days of its appearance

The use of decortication in empyema is often very satisfying [14–16 18] The employment of extirpative surgery, removing the most involved lobe, decortication of the remaining lung, and thoracoplasty, are increasing the success of the surgical therapy of empyema and are discussed in Chapter 7

The chemotherapy employed systemically has varied considerably in dosage and quantity Ten of the 30 patients received less than 100 grams of streptomycin, while 9 received more than 200 grams The largest amount any one patient received was 457 grams This latter patient died of disease progression Seventeen patients received the drug for less than six months, 8 received streptomycin for seven to twelve months, and none received it longer than eighteen months Thirteen received streptomycin alone and an equal number received the drug in combination with para-aminosalicylic acid Four patients are still hospitalized, 16 received streptomycin daily in 1 to 2 gram dosages, and in the others it was administered every third day The results in the two groups are not appreciably different, as 50 per cent are well in each group

Extent of Disease The extent of the tuberculous involvement in the lung was far advanced in 29 of the 30 patients, with roentgenographic evidence of bilateral disease in 25 patients Such extensive disease places the prognosis in a guarded category and the addition of an empyema appreciably worsens that prognosis

Cavitation Only 2 of the 30 patients did not have roentgenographic evidence of cavitation on the side of the empyema Six patients had cavitation in the contralateral lung

Length of Hospitalization The average of known disease duration to thoracoplasty was thirty-seven months The average period of continuous

hospitalization was twenty two months ten months preoperatively and twelve months postoperatively Twelve of the patients were hospitalized less than six months prior to thoracoplasty This does not necessarily represent the duration of the empyema preoperatively None were hospitalized longer than thirty-one months before thoracoplasty and only 2 for more than thirty-one months after thoracoplasty

Results Four of the 30 patients are presently hospitalized and all have negative sputa Of the remaining 26 patients 8 are dead Fifteen

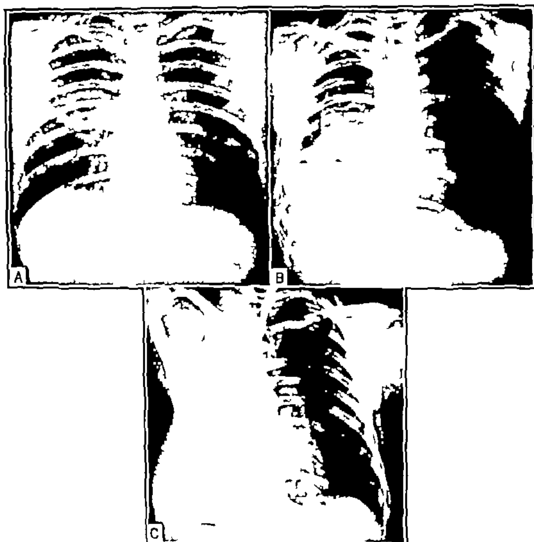


FIG 40 —Cavitary parenchymal disease, spontaneous pneumothorax, and empyema treated by chemotherapy thoracentesis, and thoracoplasty Patient is well. *A* June 26 1951 White, soldier age 21 years. Ill three months. Cavitation 3–4 cm. right, with considerable surrounding perifocal reaction. Sputum positive. *B* September 14 1951 Empyema, mixed infection type, spontaneous pneumothorax and bronchopleural fistula, right, of two months duration. Lung has partially reexpanded following repeated thoracenteses. Bronchopleural fistula has closed. Receiving viomycin. *C* November 28 1951 Thoracoplasty three stages eleven ribs right completed November 5 1951 Patient hospitalized one year post-surgery Sputum negative since operation He is well and regularly doing part time light work.

are well and working, while of the other 3, 2 have negative sputa, but are not able to work, and 1 continues to have positive sputum (Figs 40 and 41)

Summary. The collapse therapy of pulmonary tuberculosis during the chemotherapy era has been characterized by a rapid decline in its selection as the choice method of surgical therapy (see Table 3, p 68)



FIG 41 —Tuberculous empyema treated by chemotherapy and thoracoplasty *A* November 21, 1946 White, veteran, age 26 years Routine chest roentgenogram, August 15, 1946, revealed evidence of cavitation right upper lobe Sputum positive Artificial pneumothorax, right, started November 6, 1946 Cavity is open Sputum positive *B* May 8, 1947 Patient has had closed intrapleural pneumonolysis, right, performed twice and open pneumonolysis, right, performed elsewhere Admitted to Fitzsimons Army Hospital, November 16, 1947 Lung would not reexpand and a tuberculous empyema developed Suggestive cavitation, left *C* March 3, 1949 Six months after thoracoplasty, two stages, five ribs, right Lung parenchyma clear bilaterally Patient hospitalized for 11 months after surgery Sputum negative since thoracoplasty Patient is well and has been working regularly 40 hours per week since January, 1950 He received 112 grams of streptomycin

Extrapleural thoracoplasty has been the one procedure which has continued to be employed on a large scale. Its use has been chiefly in association with extirpative surgical methods. As an independent method of choice it is being used in about 10 per cent of patients. The results of extrapleural thoracoplasty employed independently during the earlier phase of this era were very satisfactory but the benefits of chemotherapy in bringing about resolution and localization of the pulmonary disease process has lent itself so well to extirpative surgery that thoracoplasty, as an extensive operation requiring the removal of more than five ribs, is now seldom necessary except in empyema. Several other surgical collapse therapy measures remain excellent surgical procedures finding varying degrees of favor with different authorities.

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Summary. The collapse therapy of pulmonary tuberculosis during the chemotherapy era has been characterized by a rapid decline in its selection as the choice method of surgical therapy (see Table 3, p 68)

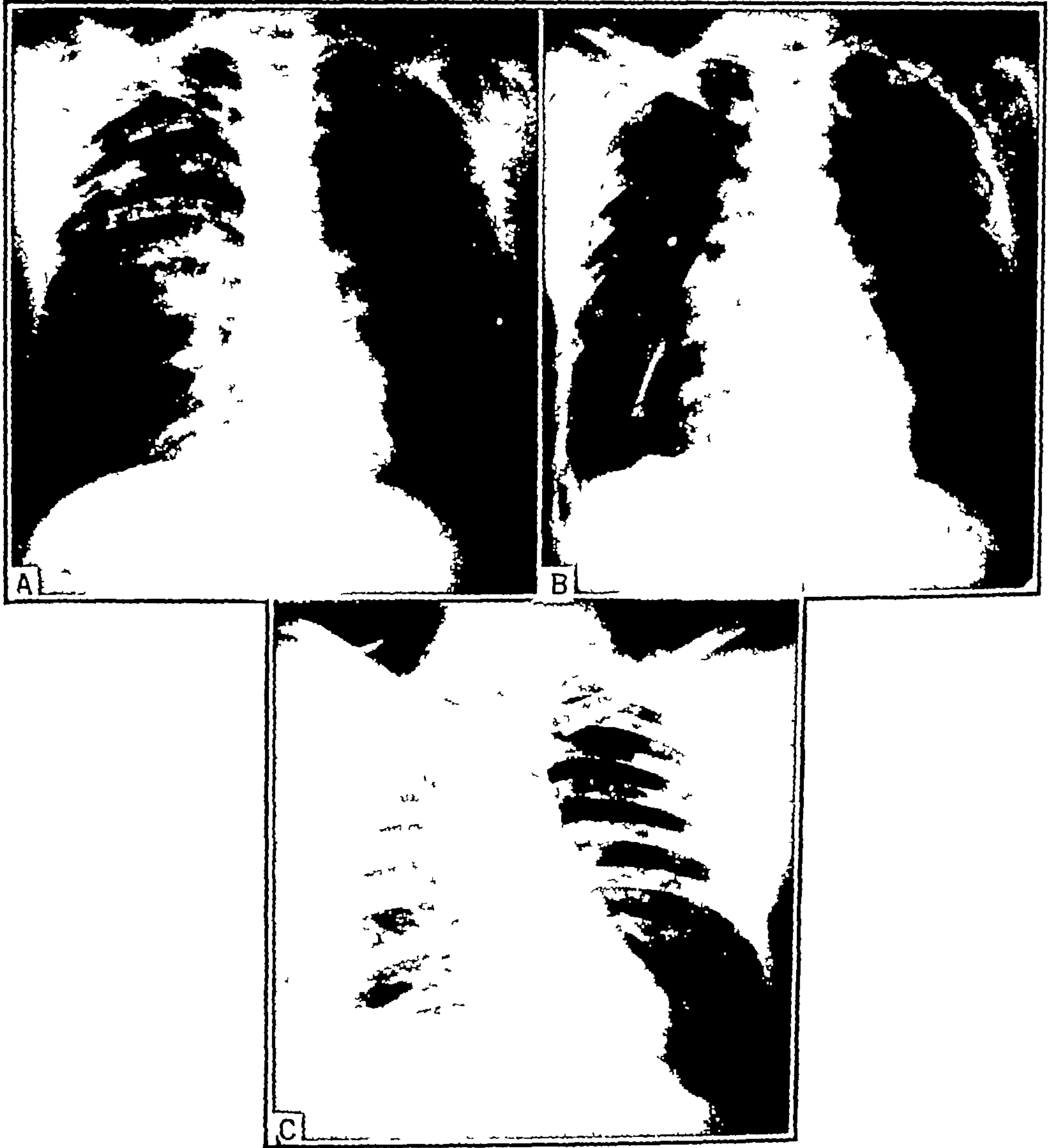


FIG. 41 —Tuberculous empyema treated by chemotherapy and thoracoplasty A
November 21, 1946 White, veteran, age 26 years Routine chest roentgeno-
gram, August 15, 1946, revealed evidence of cavitation right upper lobe
Sputum positive Artificial pneumothorax, right, started November 6, 1951
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intrapleural pneumonolysis, right, performed twice and open pneumonolysis,
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veloped Suggestive cavitation, left *C* March 3, 1949 Six months after
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Patient hospitalized for 14 months after surgery Sputum negative since
thoracoplasty Patient is well and has been working regularly 40 hours per
week since January, 1950 He received 112 grams of streptomycin

Extrapleural thoracoplasty has been the one procedure which has continued to be employed on a large scale Its use has been chiefly in association with extirpative surgical methods As an independent method of choice it is being used in about 10 per cent of patients The results of extrapleural thoracoplasty employed independently during the earlier phase of this era were very satisfactory but the benefits of chemotherapy in bringing about resolution and localization of the pulmonary disease process has lent itself so well to extirpative surgery that thoracoplasty as an extensive operation requiring the removal of more than five ribs is now seldom necessary except in empyema Several other surgical collapse therapy measures remain excellent surgical procedures finding varying degrees of favor with different authorities

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Chapter

7

Extirpative Surgical Therapy

General Considerations. The pathogenesis of pulmonary tuberculosis is characterized by the generalization rather than the localization of the disease process. This factor long deterred the therapeutic efforts directed toward the surgical removal of tuberculous lung tissue. The discovery of streptomycin and other chemotherapeutic agents administered alone or in combination has been the most effective medicament in resolving and localizing the disease, especially its pulmonary manifestations. The use of such chemotherapeutic agents, adequate bed rest, and the surgical removal of tuberculous lung tissue is now widely practiced with highly satisfactory results.

History. The historical aspects of extirpative surgery are fascinating, and reveal such efforts to have been generally unsatisfactory prior to about 1940.[14] In 1881, Block of Danzig resected the apices of both lungs in one operation, and then, upon the death of his patient, a relative, was prompted to suicide. A medicolegal inquest disclosed that the patient did not have tuberculosis. Tuffier, in 1891, resected the apex of the lung in a twenty-two-year-old male. The excised tissue "contained a tuberculous nodule the size of a small nut which was surrounded by disseminated tuberculous nodules, but there was no cavity."[14] The patient made an uneventful recovery. Tuffier proposed the early surgical removal of localized pulmonary lesions of unilateral extent. Accurate determination of the presence and location of such lesions would have been impossible prior to the perfection of the roentgenogram, but his visionary consideration of the problem is now being realized.

In 1940, Dolley and Jones summarized their own experience and that of several other leading thoracic surgeons in the United States regarding lobectomy and pneumonectomy in the treatment of pulmonary tuberculosis.[5] The indications then employed limited the clinical material to desperate case problems. Of 19 pneumonectomized patients only 3 were well and 8 were dead. Of 31 lobectomized patients 16 were well and eight were dead. Sweet continued the work of Churchill and Klopstock, and his report concerning 63 patients treated by lobectomy and pneumonectomy for pulmonary tuberculosis prior to 1946 is representative of the best results before the era of chemotherapy[1,3,22,23] (Table 21.) This work extended the indications for extirpative surgery, and excision was often performed *as the method of election in patients who presented* the usual indications for thoracoplasty. Although 103 tuberculous patients had been

treated at Fitzsimons Army Hospital by extirpative surgery, with 73 lobectomies 23 segmental resections and 7 pneumonectomies in a comparatively short period ending in 1946 the results reported in that year by Sweet led me to the temporary abandonment of the wide use of extirpative methods. Sweet expressed the need and the hope for a medicament which would overcome the invading organism and thus prevent the development of the well known manifestations of the disease by eliminating their source [72] Such a medicament is not yet available, although extirpative measures have been made feasible for extensive use through the advent of chemotherapy This emphasizes that the application of feasible concepts of therapy are often a matter of proper timing

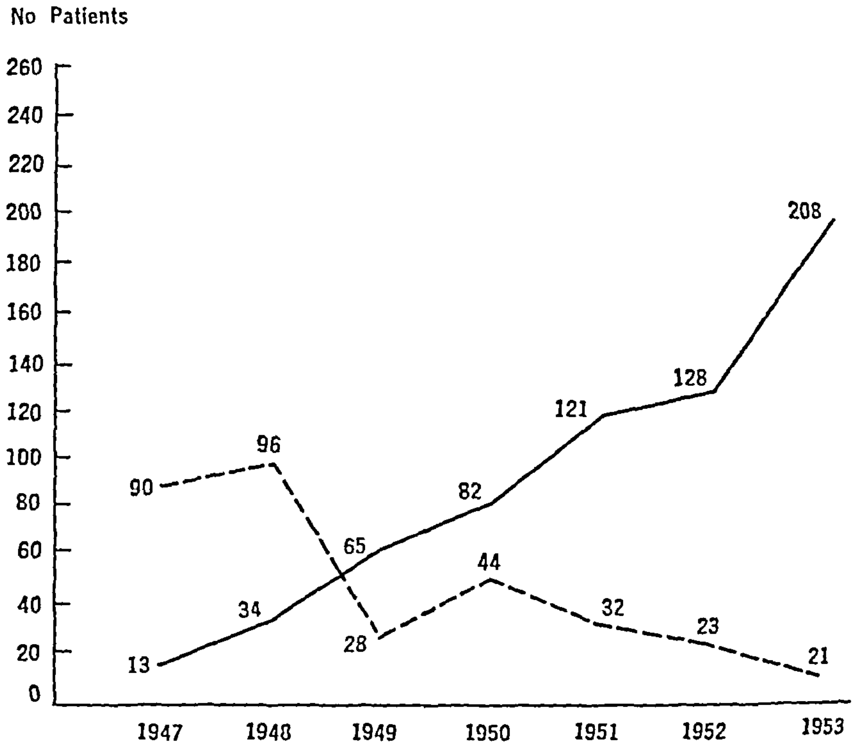
Table 21 Lobectomy or Pneumonectomy for Pulmonary Tuberculosis Prior to the Chemotherapy Era (Sweet) 3-7 Years After Surgery

No Patients	Operation	Dead	Apparently Well
27	Lobectomy	0 (33 3%)	12 (48%)
36	Pneumonectomy	10 (52 7%)	14 (30 8%)

Changing Trends Our acceptance of extirpative surgery in the treatment of pulmonary tuberculosis was characterized by a gradual extension of its use the careful evaluation of results and finally its wide application in conjunction with the new chemotherapeutic agents [7-9,24] The increased use of extirpative surgical methods and the decreasing use of thoracoplasty alone is depicted in Graph III During the period January 1 1947 through June 30 1953 651 patients were treated by extirpative surgery in the management of pulmonary tuberculosis

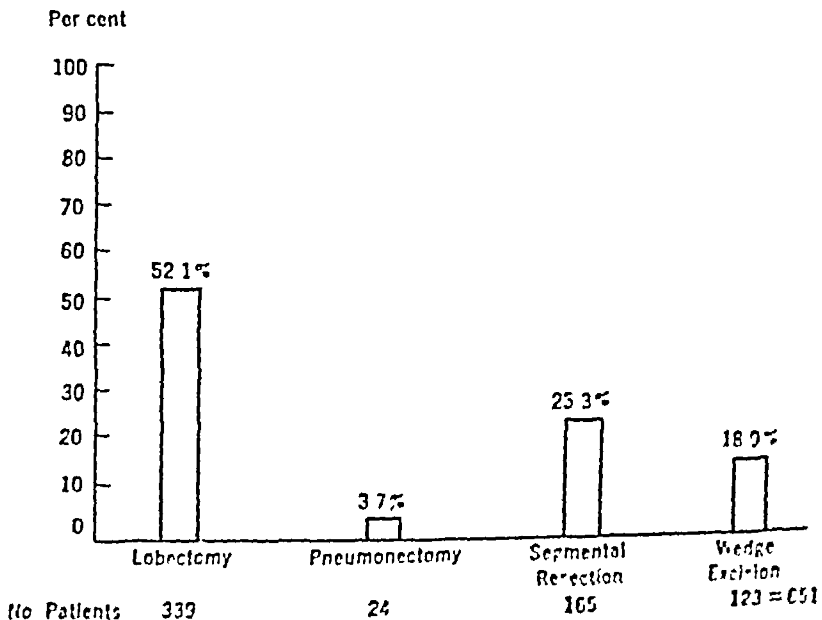
Distribution of Extirpative Procedures. The selection of the extirpative procedure is dependent principally upon the extent and distribution of the disease In general the more localized the disease the smaller is the amount of lung tissue removed The location of the lesion is important in that lesions situated close to the hilus often require more extensive removal of lung tissue than those of a similar size located peripherally Bilateral involvement requiring therapeutic measures beyond bed rest and chemotherapy may influence the extent of extirpative surgery on the more diseased side The high incidence of gross cavitary disease in the lung tissue at the time of its removal about 50 per cent of cases has influenced us to elect lobectomy in most instances (Graph IV) The anatomical structure of the lung through the arrangement of the bronchopulmonary segments permits removal of one or more diseased segments with the preservation of other normal or less involved segments The beneficial effects of streptomycin and para aminosalicylic acid in localizing the disease have steadily increased the number and percentage of patients treated by segmental resection (Graph V) Wedge excision of the localized lesion i.e tuberculoma and residual foci has also steadily increased

*Graph III. The Increasing Use of Extirpative Surgery and the Decreasing Use of Thoracoplasty 1947-1953**



* Estimated from first half of 1953
——————— Extirpative Surgery — Total No Patients = 651
– – – – – – – Extrapleural Thoracoplasty — Total No Patients = 325

*Graph IV Distribution of Extirpative Procedures 1947-1953**

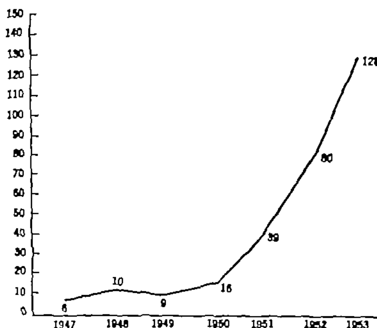


* Estimated from first half of 1953

Concepts Practiced in Extirpative Surgery It is evident from the distribution of the extirpative procedures employed that pneumonectomy has seldom been considered as indicated and that lobectomy has been the preferable procedure. Further the effectiveness of chemotherapeutic agents has resulted in a marked increase in the use of procedures directed toward removing the localized lesion and preserving a considerable portion of the normal or less involved lobe

The first concept practiced has been the recognition that tuberculosis is a generalized disease usually clinically manifested in the lungs. The involvement is usually bilateral although roentgenographic evidence may be doubtful or lacking as concerns the less involved side It is repeatedly

*Graph V Increasing Use of Segmental Resection and Wedge Excision of Tuberculous Lung Tissue 1947 1953**



* Estimated from first half of 1953

noted at operation that except for the well-circumscribed tuberculoma the remaining ipsilateral lung tissue contains visible and palpable tuberculous nodular lesions, even though recent roentgenograms are interpreted as negative. If it were feasible to examine the contralateral lung in a similar manner it is believed that it would often reveal previously undetected nodular lesions. Thus the therapeutic surgical removal of tuberculous lung tissue does not imply in many instances that the total disease area is extirpated but that rather the most involved portion is removed This results in decreasing repeated endogenous reinfections and aids in healing the remaining infected tissue by relieving the body of its chief site and

source of disease The balance then shifts to favor the reparative forces of the host in overcoming the effects of the remaining disease

The second concept practiced has been that a period sufficient to permit resolution of the new exudative lesions is allowed to elapse before extirpative measures are accomplished The time required is variable and dependent upon factors not thoroughly understood Gradually, clinical and experimental studies have developed highly satisfactory methods for the administration of chemotherapeutic agents closely coinciding with the increased employment of the surgical removal of lung tissue The chemotherapy agents are most beneficial in recently developed disease and have little effect on the old fibrous lesions Their chief effect is noted in four to six months, though benefit may continue for several months and the maximum resolution and localization may not be accomplished until twelve to eighteen months or even longer periods of chemotherapy We have gradually increased the period of drug administration, and now generally elect surgical removal of tuberculous lung tissue, except the fibrous type of known long duration and circumscribed lesions, after six to twelve months of drug therapy Chemotherapy is usually continued four to six months after operation The effect which such protracted drug therapy will have on the need for long hospitalization is problematical Our tendency has been to decrease the period of hospitalization following surgery It is also probable that, under suitable conditions, the period of hospitalization before surgery may be decreased, although we have not as yet advocated such a policy The steady decrease in the incidence of empyema associated with extirpative surgery, along with the increasing use of segmental resection in which lung tissue is transected, is further evidence of the effectiveness of the chemotherapeutic agents in decreasing the incidence of this complication The examination of surgically removed tuberculous pulmonary tissue treated with streptomycin often reveals areas of fibrous scarring in which there is a suggestion that submiliary tubercles has been present but have undergone fibrous organization.[16 21]

Until more accurate methods of measuring the degree of the healing of new exudative lesions are available, it is necessary to continue to employ additional aids in determining the proper time interval from disease onset to surgical intervention These aids include an evaluation of the clinical history, nature and course of the disease, physical examination findings, interpretation of serial roentgenographic examinations of the chest including apical, oblique, lateral or other special projections, determinations of acid-fast bacterial content of the sputum, bronchoscopic examination and microscopic study of sputum aspirated by bronchoscopic instrumentation, erythrocyte sedimentation rate, daily temperature determination, and weight variations In a few instances untoward reactions to the chemotherapeutic agents may necessitate an alteration in the timing of extirpative measures The concept of the application of surgery in a large percentage of patients within one year from the onset, is in marked contrast to the practice before the chemotherapy era[6] Military personnel are fortunate in that roentgenograms of the chest are required on entrance into the service and repeated on the slightest indication, thereby permitting early disease detection and the application of proper therapy

A third and an essential concept practiced at Fitzsimons Army Hospital has been that the removal of a considerable amount of tuberculous lung tissue should be preceded, accompanied, or followed by thoracoplasty collapse of the upper chest wall. It has been our practice to precede extirpative surgery wherein lobectomy or pneumonectomy is contemplated by one or two stages of upper phase thoracoplasty. The first stage, removal of the upper three ribs, is accomplished three weeks before lobectomy or pneumonectomy, and the second stage is performed at the time of excisional surgery by removing the fourth and fifth ribs as in the standard thoracoplasty operation. If the entire thoracoplasty is accomplished at the time of extirpative surgery, smaller segments of ribs are apt to be removed, resulting in poor chest wall collapse. If thoracoplasty is regularly deferred until two to four weeks after extirpative surgery, expansion of the remaining lung tissue has already occurred and the lung has become adherent to the chest wall. Thoracoplasty at this time fails to prevent the remaining lung from filling the space resulting from the removal of a lobe, and instead a portion of the expanded lower lobe is collapsed.

The use of thoracoplasty as a space-closing procedure in relation to extirpative surgery is controversial and must await a long term evaluation made by comparing results achieved with and without its use. The decision as to the extent of the surgical extirpation and the application of thoracoplasty or other space-closing measures is a responsibility of the surgeon, and it may occasionally be made only after exposing the lung and assessing the extent of disease. This decision should take cognizance of the previous roentgenographic studies, the clinical course of the disease, and the tuberculous seeding of the lung tissue not removed. I believe that thoracoplasty, usually removing five ribs, is the best space-closing procedure presently available. Chest wall deformity following lobectomy and a five-rib thoracoplasty is not noticeable (see Fig. 9, p. 32). Its application on the basis that the expansion of the remaining lung tissue containing latent or active tuberculous lesions is undesirable and preventable by thoracoplasty is practical and feasible. The use of plastic substances to close the space following lobectomy or pneumonectomy has been advocated by several authorities.[11,12]

In some instances the excised lobe is markedly shrunken. The remaining lung tissue has minimal or no involvement and has for a considerable period occupied much of the space reserved for a normal sized lobe. This precludes the need for a space-closing procedure. When less than one-half of a lobe, except the right middle lobe, is removed a thoracoplasty is usually not recommended unless there is appreciable involvement in the remaining lung tissue. If in such instances a first stage thoracoplasty has preceded the extirpative surgery, the fourth rib is resected to permit operative entrance into the thoracic cavity, and further rib resection is not accomplished.

A fourth concept concerns the period of hospitalization following extirpative surgery and is also in the controversial phase. It was our practice prior to 1952 to insist upon a minimum of one year hospitalization to follow lobectomy or pneumonectomy, and, in fact, little deviation from this policy is now practiced. However, the capacity of the chemo-

therapeutic agents and bed rest to bring about resolution and better localization of lesions which a few months earlier were rather widely disseminated, has called for a restudy of the period of post-surgical hospitalization. The final answer must await a longer period of evaluation of the rather rapidly changing surgical practices in the treatment of pulmonary tuberculosis As a working basis we recommend and carry out the following A conference by members of the Chest Surgery Review Board, consisting of the surgeon, phthisiologist, and others of the tuberculosis therapy team, is held weekly and recommendations are made concerning the length of hospital stay of patients treated surgically during the previous two months This decision relies heavily upon the findings at operation The extent of the disease, including both that removed and that remaining, and the histopathologic study of the excised tissue, are paramount considerations The general working rule is that military personnel who have had a circumscribed pulmonary granuloma removed, are returned to active duty in forty-five to sixty days if the lesion contains no tubercle bacilli by bacteriologic study of the surgical specimen, and if the lesion, caseous or not, was otherwise undiagnosed If in such a lesion tubercle bacilli are demonstrated, chemotherapy is continued for three to four months and usually six to eight months of hospitalization following surgery is recommended If the active area of disease is sufficiently well localized to permit segmental resection of less than one-half of one lobe, exclusive of the right middle lobe, and the remaining lung tissue is uninvolved or only to a minimal extent, chemotherapy is continued four to six months and maximum hospital benefit may usually be anticipated within six to twelve months after operation

In disease of such extent as to require lobectomy, it is generally observed that other significant disease foci are also present in the lungs, and best results will be obtained if a period of one year of hospitalization after surgery is urged The same recommendation is ordinarily made where pneumonectomy has been performed Chemotherapy in each instance is continued four to six months or longer after surgery The patient is advanced through the classes indicating improvement as warranted, and is not discharged until the disease is considered inactive for three to six months If chemotherapy has been administered for twelve to eighteen months before surgery, and the sputum has been negative for three or more months prior to surgery, the period of postsurgical hospitalization has been reduced, under favorable circumstances, to six to nine months These working plans must be individualized and not arbitrarily applied, but the patient's acceptance is best when the program is outlined in advance He has an end-point in sight which is beneficial in his meeting the challenge of recovery from pulmonary tuberculosis, and the post-hospitalization plan of further rehabilitation must begin long before the patient is discharged from the hospital

The application of these four concepts, namely, that tuberculosis is a generalized disease, that a sufficient period of chemotherapy should precede extirpative surgery, that thoracoplasty should preferably be accomplished, at least the first stage, prior to lobectomy or pneumonectomy, and that a sufficient period of hospitalization should follow extirpative

surgery is rapidly widening the sphere of the surgical removal of tuberculous lung tissue thereby permitting earlier surgery quicker inactivation of the disease shorter periods of hospitalization and decreased dangers of reactivation

Lobectomy *Indications* The indications for lobectomy have gradually evolved in orderly array from experience [1–4, 7, 9, 13–15, 19, 22, 23] In the absence of recognizable surgical contraindication the following have been the indications which we have followed (1) The removal of the tuberculoma like lesions which are not suitable for wedge excision or segmental resection

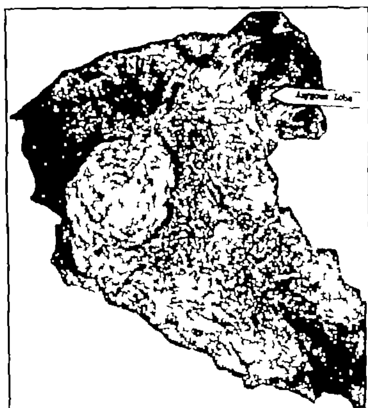


FIG 42 —Lobectomy performed because of location of lesion near hilus and its undetermined etiology Soldier age 35 years surgical specimen of tuberculoma. Lobectomy October 25 1949 Preoperative clinical diagnosis was neoplasm. Tubercle bacilli were identified from the lesion Disease detected as a result of routine chest roentgenogram for reenlistment in the Army Patient is well and has been regularly attending college for two years.

(2) Persistent cavitary disease involving principally one lobe Bronchostenosis of the lobe bronchus further increases the indications for lobectomy and patients in whom thoracoplasty has failed to close upper lobe cavitary lesions are included (3) Persistent chronic non-cavitary disease involving principally one lobe The nodular lesions are widely distributed and not suitable for wedge excision or segmental resection This group presents rather wide individual variations and causes divergent opinions among competent phthisiologists and surgeons The increasingly longer periods of chemotherapy administration encourage greater resolution and

localization of lesions, but there are an appreciable number of case problems in which the localization within the lobe is insufficient to permit segmental resection Eighty-two patients, or 18 1 per cent of the patients treated by extirpative surgery during 1947–1952, required lobectomy for non-cavitary disease The results are among our best (4) Certain suspected but unproven chronic tuberculous lesions confined to one lobe but not sufficiently localized to permit segmental resection

The grouping of indications based on the nature of the disease process, *i e*, whether (1) cavitary, (2) non-cavitary, (3) tuberculoma, or (4) of suspected but unproven tuberculous etiology, is a convenient and descriptive listing There were 163 in the cavitary group, 82 non-cavitary, and 16 suspected tuberculosis in our experience during 1947–1952 This includes 23 patients treated for tuberculoma lesions

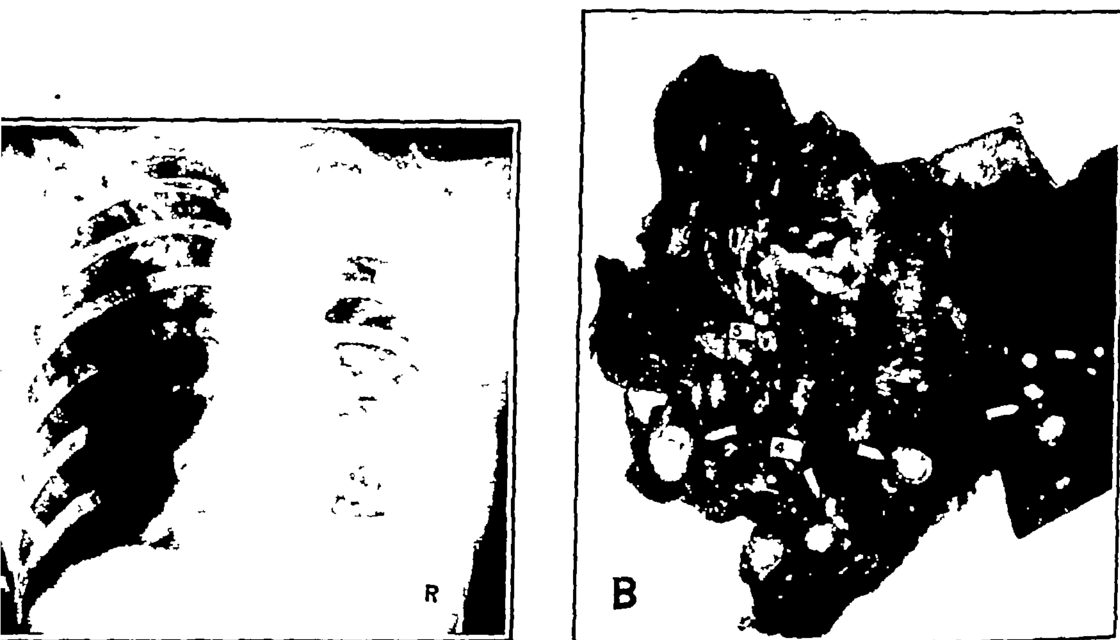


Fig 43 —*Markedly shrunken diseased lobe treated by lobectomy* *A* December 2, 1946 *B* Surgical specimen Right upper lobe which is shrunken to approximately one-sixth normal size and fibrotic There was no cavity Female, age 27, ill since 1939 Multiple therapeutic procedures were employed including bilateral artificial pneumothorax and hemidiaphragmatic paralysis, right, prior to 1946 Thoracoplasty, six-rib, left, and right upper lobectomy performed in 1948 and 1949 respectively Patient is well and has been working as a manicurist for two years Decortication, right, improved function

In the consideration of lobectomy, the contralateral lung should be roentgenographically clear or under adequate therapeutic control The use of contralateral pneumothorax in patients treated by extirpative surgery has declined rapidly since chemotherapy The location of the lesions within the lobe may determine whether or not lobectomy is indicated Lesions close to the hilus, even though considerably limited in extent, often require lobectomy for their removal, whereas similar lesions situated peripherally are suitable for segmental or wedge resection A

lesion of undetermined nature may require the performance of lobectomy. It is our practice to recommend removal of a single involved lobe if the opposite lung and the remaining lung tissue on the same side are uninvolved in certain instances in which a proper diagnosis cannot otherwise be established (Fig 42)

The indications for lobectomy may be influenced by the ineffectiveness of other therapeutic measures. The use of artificial pneumothorax therapy has decreased rapidly during the chemotherapy era When ineffective it has been a cause leading to the performance of lobectomy in 48 patients in our group The presence of a markedly shrunken lobe in which segmental resection or wedge excision would not result in the conservation of a significant amount of lung tissue is an indication for lobectomy (Fig 43)

Briefly lobectomy has been the extirpative procedure we have considered most useful and most widely employed in the chemotherapeutic era of the surgery of pulmonary tuberculosis As the experience of this era has increased and chemotherapeutic and surgical methods have improved lobectomy has given way in an appreciable measure to segmental resection and wedge excision as the choice of the extirpative procedures[1] In 1950, our data reveal that lobectomy was performed on 60 tuberculous patients as compared to 16 on whom segmental or wedge resection was accomplished In 1952 the situation has markedly changed there were 45 treated by lobectomy as compared to 80 treated by segmental or wedge resection On *the basis of experience of the first six months of 1953 these latter procedures* have been applied to 288 patients during 1947–1953 and 208 will have been performed in 1952 and 1953 (see Graph V)

Age Race and Sex Of the 261 patients on whom lobectomy was performed during 1947–1952 202 were males whose average age was thirty years 59 were females and their average age was twenty nine Two hundred thirty five were Caucasians 23 were Negroes and 3 Asians. The age in relation to the nature of the disease is presented in Table 22

***Table 22.** Lobectomy for Pulmonary Tuberculosis Age of Patient in Relation to Nature of Disease 261 Patients 1947 1952*

Age	*Cavitary*	*Non-cavitary*	*Suspected*	*Total*
21 or less	31	8	1	40
22–30	71	33	7	111
31–40	46	27	6	79
41–50	14	13	2	29
51+	1	1	0	2
TOTAL	163	82	16	261

Effect of Disease Duration on Results The determination of the duration of the disease is often difficult and lacks exactness The initial positive bacteriologic finding history of previous therapy such as bed rest or collapse therapy or the knowledge that a spot on the lung was noted on previous roentgenographic examinations are significant but the disease may be of months or even years duration when first detected Thus in-

terval may allow considerable healing, but the balance between disease progression and resolution is often delicate With the increasing use of routine chest roentgenographic examinations, abnormal shadows suggestive of pulmonary tuberculosis are being brought to the clinician's attention with a markedly increased frequency, and these require decisions as to their management There is considerable tendency to defer surgical therapy in proven or suspected tuberculosis, based on the knowledge that an appreciable number of patients recover without its use Surgical therapy will accomplish most when applied to patients in whom the mortality rates may reasonably be expected to be low, when the morbidity in comparison to an indefinite bed rest regimen will be lessened, and when immediate and long term results will be better than that reasonably expected by other management methods

Table 23. Data Concerning Patient's Age, Disease Duration of 6 Months or Less, and Result. 57 Patients

Age (years)	*No Patients*	*Dead*	*Not Working (Sp Pos)*	*Hospitalized Sp Neg*	*Disease Inactive Hospital Discharge 1952*	*Well & Working*	*Well, Working, and Anticipated Complete Rehabilitation*
21 or less	6	0	0	0	1	5	6
22–30	17	0	0	0	7	10	17
31–40	22	0	2	1	6	13	20
41–50	12	2 (non tbc)	0	1	2	7	10
TOTAL	57	2	2	2	16	35	53 (93%)

Throughout this treatise, emphasis has been placed on the relatively early application of surgery in conjunction with chemotherapy in the treatment of pulmonary tuberculosis In considering 261 patients treated by lobectomy during 1947–1952, this thought is further elucidated Fifty-seven, or 22 per cent of the patients, had a known disease duration of six months or less prior to lobectomy Thirteen of this group were far advanced, 39 moderately advanced, and 5 had minimal disease There were no operative deaths, and 93 per cent are well and working, able to work, or their condition is such as to anticipate their returning to work as soon as sufficient time has elapsed since lobectomy (Table 23) If the duration of disease was thirteen to eighteen months, the results were less favorable It might be predicted that the best results would be in those patients whose disease duration was between these two groups With disease of a comparable extent there was, however, no significant improvement over those of shorter duration Of 109 patients whose disease duration prior to surgery was seven to twelve months, 90 per cent are presently working or it seems assured that they will be able to work as soon as sufficient time has elapsed since operation to permit that recommendation Actually slightly more than one-half of the patients treated by lobectomy and discharged in 1952 are actually working regularly forty hours per week, although in many instances sufficient time has not elapsed for us to make such recommendations

Effect of Age and Short Disease Duration on Results In my experience there is no evidence to indicate that short duration of disease in young adults unfavorably influences the results or that they become better surgical risks or the disease more amenable to surgery by delaying operation Lobectomy for pulmonary tuberculosis in conjunction with chemo-

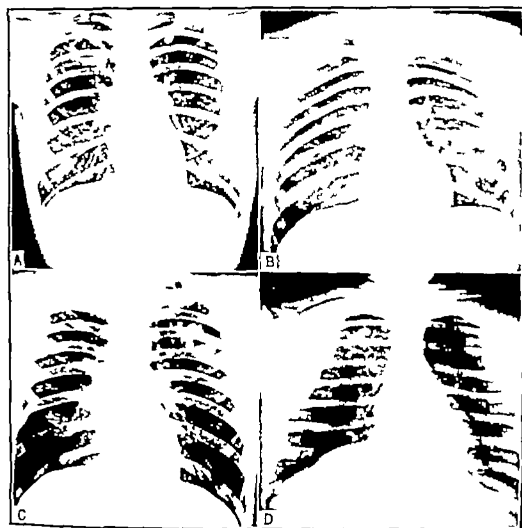


FIG 44 —Illustrative cases of young adults with short disease duration treated by lobectomy *A* Female, age 27 onset to lobectomy 12 months two cm cavity and endobronchial involvement in removed lobe. Chemotherapy 108 grams of streptomycin and 1420 grams of para-aminosalicylic acid. Patient well and working two years after right upper lobectomy and five-rib thoracoplasty *B* Soldier white male, age 18, sputum negative but tubercle bacilli identified and small cavitation noted in surgically removed left lower lobe. Patient well and doing part time farm work 16 months after surgery Chemotherapy Streptomycin 22 grams and para-aminosalicylic acid 348 grams. Onset to lobectomy seven months. *C* Soldier white male age 26 onset to right upper lobectomy and five-rib thoracoplasty 12 months One cm. cavity in surgical specimen. Patient well and working regularly as glass engraver since two years after surgery *D* Airman male white age 28. Onset to right upper lobectomy and five-rib thoracoplasty seven months. Patient well and working regularly as flight control clerk since two years after surgery

therapy has reached such a high degree of effectiveness, with complete rehabilitation of approximately 90 per cent of the patients seemingly assured, that delay in its application beyond that necessary to obtain maximum benefit of chemotherapy is unwarranted if the indications enumerated are present. This bright picture is capable of wide achievement (Fig 44)

Extent of Disease and Effect on Results The extent of the tuberculous disease in patients treated by lobectomy is depicted in Table 24 These data are indicative of the widening of the sphere of extirpative surgical therapy in pulmonary tuberculosis During the years 1947 and 1948, 186 patients were treated by means of extrapleural thoracoplasty, which comprised 80 per cent of our major surgical efforts At that time, I felt that surgery was being widely applied With no appreciable change in the patient census, 232 patients were treated by extirpative surgery during 1952 and the first six months of 1953, representing 88 8 per cent of the major surgical efforts The increase has been in the group of patients with moderately advanced disease There has also been a steady decrease in complications, with a gratifying lessening of mortality and morbidity Chemotherapy has been the common denominator influencing this change As would be expected the results are better in patients with moderately advanced disease as compared to those having far advanced disease Ninety-five per cent of the former are well, working, able to work, or the prognosis for complete rehabilitation is excellent as compared to 78 per cent of patients with far advanced disease reaching this goal

Table 24. Extent of Disease 261 Patients Treated by Lobectomy 1947-1952

Extent of Disease	*Cavitary*	*Non-cavitary*	*Suspected*	*Total*
Far Advanced	81	10	0	91 (35%)
Moderately Advanced	82	69	11	162 (62%)
Minimal	0	3	5	8 (3%)
TOTAL	163	82	16	261

In evaluating the effect of disease extent according to the classification of cavitary, non-cavitary, suspected, or the tuberculous lesions, the cavitary lesions are indicative of increased severity of the disease process Eighty-six per cent of all patients with evidence of cavitation in the removed lobe are well and working, able to work, or their prognosis is so favorable as to anticipate their complete rehabilitation to a work capacity status as soon as sufficient time has elapsed to recommend such activity In the 82 patients on whom lobectomy was performed for non-cavitary disease, 2 are dead, neither due to tuberculosis, and all others are in the work category status defined above, an unexcelled record in our experience The 16 patients having lesions suspected but unproven by bacteriologic

methods are well and working as defined above Among the 23 patients having tuberculoma lesions treated by lobectomy 3 were far advanced and 1 had minimal disease There was 1 death in the tuberculoma group thirty months after operation 1 patient is unable to work because of brucellosis while all other patients treated for tuberculoma are well and working or able to work In summary 86 per cent of the patients having cavitary lesions, 97 6 per cent of the patients with non-cavitary lesions, and 100 per cent of those whose disease is without bacteriologic confirmation

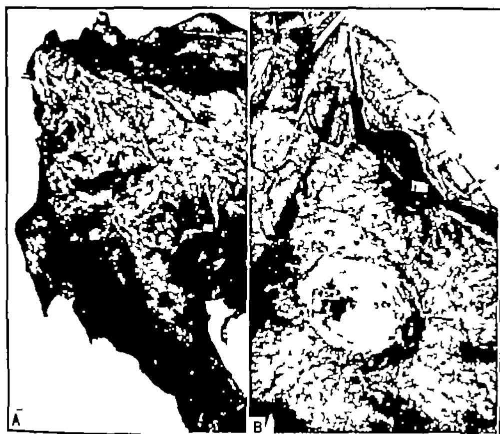


FIG. 45 —Illustrative surgical specimens of patients treated by lobectomy *A* Female age 26 onset to left lower lobe lobectomy 13 months Two and one-half cm cavity in surgical specimen. Patient left the hospital against medical advice two months after surgery Sputum positive one year after surgery Probable cavitation opposite lung Chemotherapy Streptomycin 84 grams para amino-salicylic acid, 1188 grams and tibione, 12 100 mgm. *B* Soldier male age 25 known duration to lobectomy eight months Lesion is a tuberculoma which has cavitated one and one-half cm. cavity in surgical specimen Chemotherapy Streptomycin, 64 grams. He is well and working as a farmer 18 months after left upper lobe lobectomy and five-rib thoracoplasty

are well working able to work or it is anticipated that they will soon be able to work. The over all appraisal of end results and rehabilitation indicates that 90 per cent of all patients treated by lobectomy have reached or will reach this goal a striking contrast to the approximately 10 per cent of the group of 511 patients treated by thoracoplasty at Fitzsimons during

the period 1926–1946, the pre-chemotherapy era (see Table 2, p 51) This represents a statistical alteration of improvement of 800 per cent These facts become even more significant on recalling that only approximately one-half of the original 511 patients treated by thoracoplasty, prior to the chemotherapy era, were surviving when a study was made in 1950 In order that these data will not be misconstrued as suggesting that the extent of the disease in the group of patients treated by thoracoplasty during 1926–1946 and those treated by lobectomy during 1947–1952 was essentially the same at the time of operation, it is emphasized that although exact information is lacking, it is reasonably certain that more than 80 per cent of the former group were in the far advanced classification as compared to 35 per cent of those treated by lobectomy It is not the surgical procedures which warrant comparison but rather emphasis is directed toward the improved general condition of the patient, and to earlier application of surgical therapy made possible to a major degree by chemotherapy (Fig 45).

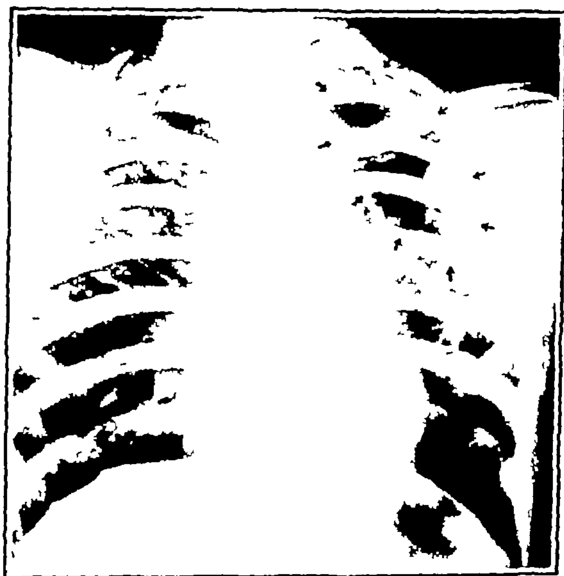


FIG. 46 — Lobectomy for thoracoplasty failure A tremendous excavation left upper lobe Two years after eight-rib thoracoplasty, sputum positive and lobectomy was performed Sputum became negative He is well and has been employed as a policeman since two years after lobectomy

Multiple Extirpative Procedures No more striking description of the chemotherapy era is evident than the now infrequent use of multiple extirpative surgical procedures in comparison to their very common practice before the wide application of extirpative surgery Of the 261 patients treated by lobectomy only 21 had lung tissue other than the lobe removed, this included wedge excision or segmental resection of the adjacent upper or lower lobe The combined removal of the right middle lobe along with the right lower or right upper lobe is included as a single lobectomy Only 2 patients treated by lobectomy have subsequently had the remaining lobe or lobes on the operated side removed We have no experience with bilateral lobectomy for pulmonary tuberculosis We have also been reluc-

tant to employ bilateral extirpative measures for the removal of residual foci from both lungs. In the concept of extirpative surgery I have advised and applied thoracoplasty for 96 per cent of the patients treated by upper lobectomy or pneumonectomy. Seventy four per cent exclusive of the thoracoplasty failures were of the five-rib thoracoplasty type. Twenty of the 261 patients or 7.6 per cent had lobectomy performed because of thoracoplasty failure in closing the cavitation (Fig. 40).

Cavitation. Cavitation evidenced roentgenologically prior to 1947 was present probably in excess of 80 per cent of the patients treated by thoracoplasty. The changing trends in surgical therapy are easily detected by noting that only 62 per cent of the lobes removed during 1947–1952 evidenced cavitation. The size of the cavitation in the excised tissue represented the minimal cavity size and in 163 patients was as follows: 1 cm 36, 2 cm 47, 3 cm 33, 4 cm 11, 5 or more cm 12, and in 24 patients the measurements were not recorded. Eighty-one of the patients were further classified as having far advanced and 82 as having moderately advanced disease. In our experience results cannot be predicted on the basis of the size of cavitation. The smaller cavitary lesions doubtless respond better than larger ones to bed rest, chemotherapy and surgery. Of the 15 patients who died, 7 had cavitary lesions measuring 3 centimeters in diameter in the surgically removed lobe and in 1 patient the cavitary size was not recorded. The disease process was inactive in one of the patients while 14 had active disease at the time of death. In the entire group treated by lobectomy the number of patients with cavitary disease who are ill, unable to work and in whom the prognosis is guarded is only 9. Three had cavities measuring 3 centimeters or less and in 6 the cavitary lesion measured more than 3 centimeters in diameter. Two other patients are disabled because of other disease. In classifying the extent of disease on roentgenographic findings and the clinical course of disease certain discrepancies are inevitable. However there is rather close correlation in this group of 163 patients. The classification of only four would definitely have been changed as a result of cavitary size alone, *i.e.* the 4 patients with cavitary lesions of 4 centimeters or more classified in the moderately advanced group would have been placed in the far advanced category.

The estimation of cavitary size from roentgenograms may be misleading. Seven patients presumed to have giant cavitation preoperatively had cavities measuring less than 5 centimeters in the surgical specimen while 5 patients whose roentgenographic examination did not indicate giant cavitation had such lesions demonstrated in the surgical specimen. Multiple cavitation has seldom been noted in the surgically excised lobe. Only 5.7 per cent or 15 patients had cavitation on the opposite side as determined by roentgenographic findings within six to twelve months prior to lobectomy.

Cavity size in relation to disease duration and surgical results was studied. In the 81 patients with cavitary disease classified as far advanced the disease duration was as follows: Six months or less 12, seven to twelve months 26, *i.e.* 47 per cent had a known duration of twelve months or less. Of these, 3 are dead and 4 are unable to work, 3 because of tuberculosis. The others are well, able to work, working or their prognosis is

excellent and they should be able to return to work as soon as the recommended period of rest is completed. The diameter of the cavitary lesion in these 38 patients with disease duration of one year or less was 1 cm., 9; 2 cm., 11; 3 cm., 8; 4 cm., 3; 5 cm., or more, 4; in 3 patients the size was not recorded. At the opposite end of the scale of disease duration there are 14 patients whose known duration is sixty months or more. The diameters of the cavitary lesions noted in the surgically excised specimens were 1 cm., 3; 2 cm., 2; 3 cm., 3; 4 cm., 2; 5 cm. or more, 3; and in 1 patient the size was not stated. Two of the 14 patients are dead. Only 1 of the surviving patients is unable to work. This patient also has carcinoma of the uterus. Such a comparison offers no evidence to indicate that prolonged delay in carrying out extirpative surgery is beneficial. The comparison fails to emphasize the dangers of disease progression with fatal termination, or the increased risk of surgical therapy. In addition, the hazard of spreading the disease to others because of expectorating sputum containing tubercle bacilli is a most significant public health consideration and lends encouragement to the concept of surgical therapy applied relatively early during the course of the disease. In the remaining 29 patients with far advanced cavitary disease the known disease duration was thirteen to eighteen months in 9 patients, nineteen to thirty months in 4 patients, and thirty-one to sixty months in 16.

Table 25. Duration of Chemotherapy, 233 Patients Treated by Lobectomy

Months of Therapy	*Cavitary*	*Non-cavitary*	*Suspected*	*Total*
6 or less	102	47	12	161
7–12	42	20	2	64
13–19	8	0	0	8
TOTAL	152	67	14	233

Chemotherapy. The chemotherapeutic regimen of combined, intermittent therapy consisting of streptomycin, 1 or 2 grams every third day, and para-aminosalicylic acid, 12 grams daily, was well standardized by the time most of these 163 patients with cavitary lesions were treated by lobectomy, as 88 per cent were operated upon after 1949. The data concerning the duration of chemotherapy in 233 of the 261 patients treated by lobectomy, and who have been discharged from the hospital are summarized in Table 25. The amount of streptomycin administered was, however, frequently greater than that which would be given over the period of the standard, combined, intermittent regimen as the dosage was often 1 or 2 grams of streptomycin daily, rather than every third day. The dosage of streptomycin in relation to disease duration is shown in Table 26. Eighty-four per cent of 226 discharged patients with moderate or far advanced disease received 200 grams or less of streptomycin. Two-thirds of the patients with far advanced disease had more than 100 grams of the drug, as compared to one-third of those having moderately advanced disease. Approximately 1 out of every 4 of these 226 patients had a known disease

duration of more than thirty months The dosage of streptomycin in this latter group was about equally divided between those having had 100 grams or less and those having had 101 to 200 grams

Prolonged duration of disease *i.e.* sixty months or more was noted in 14 of 81 patients with far advanced cavitary disease treated by lobectomy A shorter period and smaller dosage of chemotherapy might suggest itself in this group Actually this was not the case as the duration of chemotherapy was equally divided between those patients receiving streptomycin *for six months or less, and those receiving the drug for longer periods i.e.* seven to twelve months The dosage of streptomycin in these 14 patients was 100 grams or less in 4 patients 101 to 200 grams in 8 patients and more

Table 26 Lobectomy for Pulmonary Tuberculosis Dosage of Streptomycin in Relation to Extent and Duration of Disease

Amount of Streptomycin grams	*Disease Duration—Months*					
	6–Less	*7–12*	*13–18*	*19–30*	*31+*	*Total*
Less than 100						
Far Advanced	4	9	5	3	6	27
Moderately Advanced	27	30	4	2	19	82
Minimal	5	1				6
101–200						
Far Advanced	8	12	3	0	21	42
Moderately Advanced	10	35	6	2	3	56
Minimal		1				1
201–300						
Far Advanced	2	2	1	0	3	8
Moderately Advanced	0	2	1	0	2	5
301–400						
Far Advanced					1	1
Moderately Advanced			1			1
401+						
Far Advanced		2			2	4
Moderately Advanced						
TOTAL	51	94	21	7	57	233

than 200 grams in 2 patients None had cavitary lesions measuring more than 3 centimeters *in the surgically removed lobe* *The determination of* the dosage of chemotherapy is fundamentally a clinical appraisal of the extent and nature of the disease process This appraisal is best made by the physician who carefully studies each patient maintaining and reviewing detailed case records at frequent intervals and who conducts a follow up survey on all patients entrusted to his care The accomplishment of these tasks will doubtless permit a further improvement in the chemotherapy of pulmonary tuberculosis The results of the comparison of dosage and extent of disease are shown in Table 27

Length of Hospitalization A feature common to all problems related to pulmonary tuberculosis is the length of continuous hospitalization of the patient This varies considerably depending upon the extent and nature of the disease process Early detection and immediate hospitalization are

oals for realizing the best results, and these are being attained in an ent manner in the military services The hospital stay in 236 of the atients treated by lobectomy at Fitzsimons Army Hospital has varied derably (Table 28) The average stay before surgery was nine months he average after surgery was ten months, an average total of nineteen hs

ble 27 Comparison of Duration of Chemotherapy and Results Patients Treated by Lobectomy. 233 Patients

ts	*Extent of Disease*	*Duration of Chemotherapy*	*Dead*	*Unable to Work*	*Well, Working or Anticipated-Normal Work Capacity*
	Far Advanced	6 Mos or less	8	3	34 (75%)
	Mod Advanced		3	1	107 (96 4%)
	Min Advanced		1	0	4 (80%)
	Far Advanced	7–12 Mos	4	3	25 (84 3%)
	Mod Advanced		1	1	29 (93 5%)
	Min Advanced		0	0	1 (100%)
	Far Advanced	13 or more Mos		2	2 (75%)
	Mod Advanced				4 (75%)
			17	10	206 (88 4%)

able 28. Continuous Hospitalization 261 Patients Treated by Lobectomy*

Months Hospitalization	*Before Surgery*	*After Surgery*
6 or less	79	47
7–12	110	111
13–18	49	61
19–30	15	15
31+	8	2
	261	236

* 25 patients are still in the hospital

ndobronchial Tuberculosis Prior to the wide application of extirpa- surgery, the detection of endobronchial tuberculosis was dependent bronchoscopic and post-mortem findings Present findings noted in urgically removed lobes, indicate the limitations of the former method xamination, as endobronchial involvement was observed in 36 per of all surgically removed lobes (Table 29) These findings are rather ling in view of the excellent results noted bronchoscopically following otomycin therapy for endobronchial disease This high incidence in- es, however, all gross or microscopic evidence of endobronchial disease, her considered active or inactive, and, of course, includes the closest tins of the minor bronchi not available for bronchoscopic examination variation of interpretation by different pathologists is also depicted is study

Lobectomy for Cavitary Disease Persistent cavitary tuberculous disease is the major challenge to surgery in the treatment of this disease Proper chemotherapy temporary collapse measures such as pneumoperitoneum or artificial pneumothorax therapy and bed rest will result in the arrest and inactivation of the disease in an appreciable percentage of patients with non-cavitary disease When persistent cavitation is present the conditions conducive to inactivation of the disease are much altered as a continuous source of tubercle bacilli bathes the bronchi erosion of pulmonary vascular tissues and hemoptysis may occur and dissemination to other parts of the lung is a reality in many instances No release from these dangers is assured until long after the cavity appears to be closed or the lesion is extirpated One hundred sixty-three patients with cavitary disease have been treated by lobectomy during the period 1947–1952 inclusive, and 13 additional patients during the first half of 1953 The latter group are too few to permit definitive appraisal Suffice there have been no operative deaths and there is excellent evidence to indicate that results will be equally as good as those noted earlier The over all results in this group indicate that 86 per cent are well and working or their prognosis is such as to anticipate their return to work.

***Table 29** Endobronchial Disease Based on Histopathological Examination of Surgically Removed Tuberculous Pulmonary Tissue (Lobectomy)*

No Patients	*Nature of Disease*	*Endobronchial Tuberculosis*
163	Cavitary	80 (49%)
82	Non-cavitary	12 (14 6%)
16	Suspected	2 (12%)

During the period 1947–1952 65 patients have been classified as having giant cavitation The selected method of surgery has been thoracoplasty in 38 lobectomy in 21 pneumonectomy in 4 and segmental resection in 2 This classification *i.e* one cavity of a diameter of 5 centimeters or more is dependent initially on the roentgenographic interpretation Of the 21 patients treated by lobectomy a cavitary lesion of 5 or more centimeters was present in the surgically excised lobe in 12 patients and in 5 of these roentgenographic evidence of *giant cavitation was lacking* However in 9 other patients the roentgenographic findings of a giant cavitation were not confirmed by measurements of the cavity in the removed tissue the size varying from 1 to 4 centimeters and averaging 3 centimeters Of these 21 patients classified as having giant cavitation 16 or 73 per cent are well working or able to work. This is an excellent result in disease of this extent and represents a considerable superiority over thoracoplasty alone.

Lobectomy was also performed on 20 patients for thoracoplasty failure *i.e* cavitation and positive sputum persisting six or more months after completion of thoracoplasty Fourteen of these patients, or 70 per cent are well and working Three are dead all having active disease at the time

of death Two are still positive One is hospitalized, has a negative sputum, and the prognosis is excellent

Lobectomy for Non-cavitary Disease *General* The principal reason for which lobectomy is performed for non-cavitary disease is the rather even distribution of nodular lesions throughout the lobe, with few or no lesions noted in the remainder of the lung The findings described by Colonel H W Mahon, pathologist, Fitzsimons Army Hospital, in the following case report are illustrative "The left upper lobe weighs 125 grams and measures 21 by 8 by 3 cm The pleural surface is everywhere thickened The bronchi have their normal position, size, and distribution The pulmonary parenchyma is subcrepitant and everywhere nodular Scattered throughout there are yellow, white, firm nodules varying in size from 2 mm to 1 5 cm in diameter These are more numerous in the

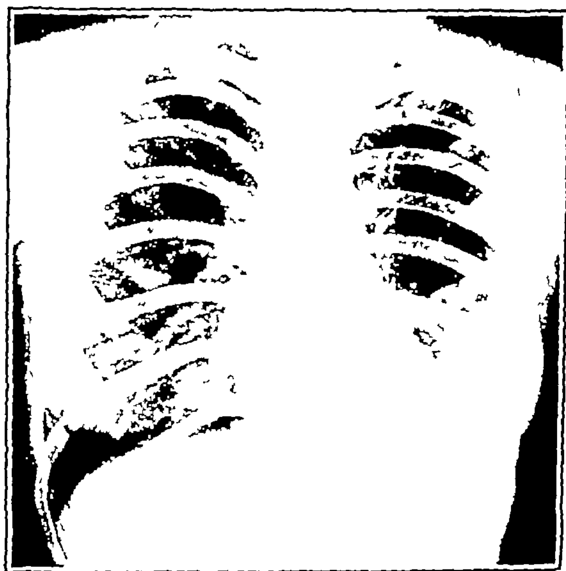


Fig 47 —Lobectomy for non-cavitary disease March 1, 1951 White, female, age 27, known disease duration of five years prior to left upper lobe lobectomy, April 26, 1951 Cavity, left upper lobe, suggested in roentgenogram but not demonstrated in surgical specimen Patient is well Chemotherapy Streptomycin, 230 grams, and para-aminosalicylic acid, 3996 grams

apicoposterior segment but only slightly less evidenced throughout the anterior segment Smears from these nodules were positive for acid-fast bacilli No cavity is demonstrated" (Fig 47) Any other extirpative procedure, except pneumonectomy, in such case problems usually results in leaving as much diseased tissue as is removed In our experience no other surgical method has equalled the results obtained in those patients treated by lobectomy for non-cavitary pulmonary tuberculosis

Roentgenographic Evidence of Cavitation Although cavitation was not present in any of the removed lobes, there was roentgenographic evidence of excavation noted in the lobe during the course of the disease in 27 per cent of the patients In several instances the scarring noted in the surgical specimen doubtless represented earlier cavitation The importance of the

clinician including the surgeon accepting responsibility for the interpretation of the chest roentgenographic examination is again emphasized as he is best able to anticipate such discrepancies

Indications Lobectomy was considered the procedure of election in 71 of the 82 patients without any therapy other than bed rest and chemotherapy In 9 it followed artificial pneumothorax failure In 2 patients neoplasm was the clinical diagnosis which led to the lobectomy and tuberculosis was evidenced after the lobe was removed and tubercle bacilli demonstrated in the excised tissue

Classification The terminology employed in classifying the tuberculous lesions surgically removed varied with different pathologists The inclusive term fibrocaseonodose appears preferable In this group of 82 patients the classification was tuberculoma in 5 fibrous in 3 caseopneumonic in 3 and fibrocaseonodose in 71 Ten were far advanced 69 moderately advanced and 3 were minimal In the variation of the types of lesions which characterized the disease process certain interesting observations are encountered The sudden onset is typical of the caseopneumonic type of disease but with increasing evidence of consolidation and atelectasis malignancy often warrants consideration (Fig 48) Tuberculous disease of several years duration fibrous and active often seems to be so hopeless that the surgeon may despair of his efforts (see Fig 43) Between these extremes are the majority of the patients treated surgically namely the fibrocaseonodose type There is often much uncertainty as to the course which the disease will pursue for there is a delicate balance between disease progression and healing If the latter wins in a long struggle the danger of reactivation is ever present The marked lessening of these hazards by properly timed extirpation is a great boon to the therapy of pulmonary tuberculosis Emphasis placed on the earlier application of surgery *i.e* six to twelve months after disease detection is becoming increasingly significant (Fig 49)

Age Race Sex and Known Duration Prior to Lobectomy The average age was thirty two years slightly higher than for the entire group of patients treated surgically The youngest was nineteen and the oldest fifty four Eight were twenty-one years of age or younger 33 were between twenty two and thirty 40 were between thirty-one and fifty while 1 was over fifty years of age Seventy six were Caucasians and 6 were Negroes. It is noted that the disease process in this category was seldom acute and at the same time the incidence of Negro patients was low there being only 7 per cent as compared to an average incidence of approximately 13 per cent of all those treated by extirpative surgery or by thoracoplasty This may suggest that Negroes respond less favorably than the white race toward the development of a relatively benign tuberculosis diease Fifty eight were male and 24 female where the hospital admissions for tuberculosis are approximately 80 per cent males

The average known duration of disease based on the demonstration of tubercle bacilli in the sputum or gastric contents was twenty two months (Table 30) Of interest is the period of hospital stay following lobectomy in patients in whom the known duration was sixty months or more before lobectomy One patient left the hospital against medical advice two months



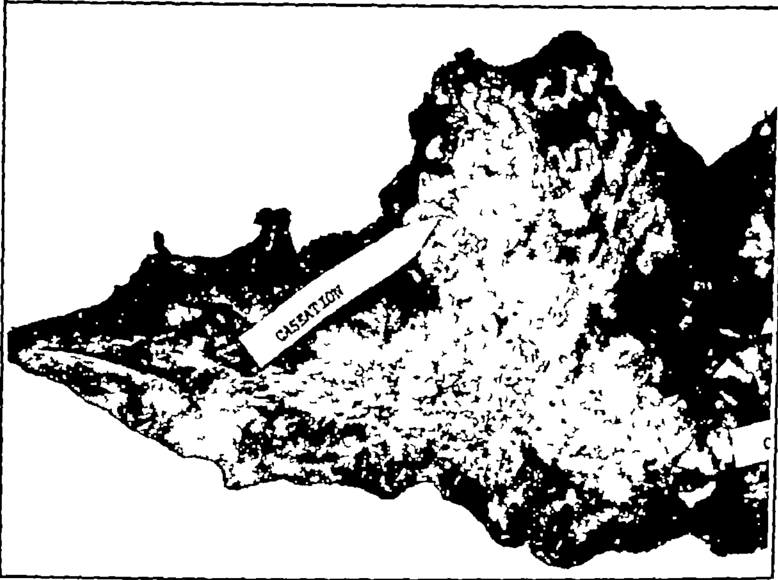
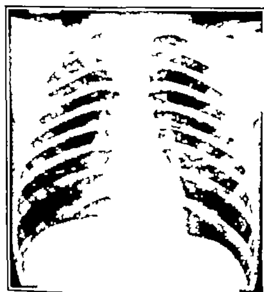
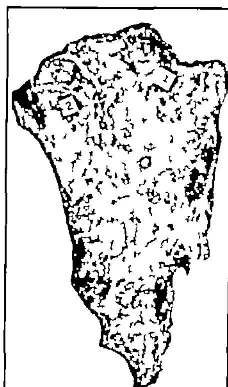


FIG 48 —Caseopneumonic tuberculosis suggestive of neoplasm *A* January 30, 1950 Sudden onset of acute pulmonary symptoms, December 10, 1949 Sputum repeatedly negative Admitted to Fitzsimons Army Hospital, March 23, 1950 The patient was asymptomatic and contraction of the upper right lobe became rather marked The diagnosis of tuberculosis was considered doubtful Right exploratory thoracotomy, April 10, 1950, revealed the lung to be adherent throughout to the chest wall by recently formed thin adhesions which bled readily on being separated and left a raw granular surface The upper lobe was very firm, containing multiple evenly distributed nodular areas Excision of one of the nodular areas was accomplished and upon examination tubercle bacilli were identified The edges of the excised area were sutured, and because of the acute nature of the lesion the wound was closed Chemotherapy has been started before operation and was continued until August, 1950, with marked resolution of the lesions Right upper lobectomy and upper phase thoracoplasty were performed during December, 1950 and January, 1951 The lesions in the removed lobe were described as diffuse caseonodose with considerable scarring and widely scattered nodular lesions of varying size Smears and culture from the lobe were positive for acid-fast bacilli He was discharged from the hospital January 23, 1952, his disease having been inactive for three months He has remained well *B* Surgical specimen, right upper lobe

after lobectomy 1 after seven months 1 required twenty-one months hospitalization and the other 6 were hospitalized approximately one year after lobectomy In restudying these 9 case problems there is every reason to believe that at the present time chemotherapy and surgical extirpation would be recommended within a few months of disease detection Precise information is not available but probably 80 to 90 per cent of far advanced pulmonary tuberculosis develops from lesions which are often considered small and insignificant with the patients often being incorrectly advised that these are innocent lesions Further it is my belief that the therapy





A *B*

FIG 49 — Lobectomy for non-cavitary tuberculosis. *A* February 20 1950 A 26-year old white soldier had been ill 15 months before lobectomy was performed. Chemotherapy was given in the form of streptomycin 2 grams every third day and para-aminosalicylic acid, 12 grams every day from September 10 1950 to December 1950 Bronchoscopy in September 1950 revealed endobronchial tuberculosis. Roentgenographic examination revealed cavitation but no cavity was present in the right upper lobe which was removed November 21 1950 His post-surgical hospitalization was 12 months. He is well and has been regularly employed 40 hours a week since July 1952 A five-rib thoracoplasty was part of the plan of therapy *B* Surgical specimen of right upper lobe removed November 21 1950

of pulmonary tuberculosis has improved so greatly during the past seven years that the failure to recommend surgery in such cases though the disease be very limited in extent is unwarranted The demonstration of tubercle bacilli in the sputum or gastric washings is not mandatory before surgery if clinical data are indicative of tuberculosis In fact such lesions tuberculous or nontuberculous are best managed by surgical exploration and their removal In most instances such case problems of tuberculous

etiology may be properly treated by segmental resection, conserving considerable normal lung tissue Age, race, and sex did not appear to influence the result in these patients

Table 30. Disease Duration Prior to Lobectomy for Non-cavitary Disease. 82 Patients

Months	*No Patients*
6 or less	19
7–12	37
13–18	11
19–24	2
25–36	2
37–60	2
60 or more	9
	82

Diagnosis It was earlier pointed out that the diagnosis of pulmonary tuberculosis may require surgical exploration of the chest, removal of suspected tissue, and histopathologic and bacteriologic examination of the excised tissue to confirm the diagnosis This requirement is well demonstrated in these 82 patients Prior to surgical exploration the diagnosis of active pulmonary tuberculosis had not been proven by the demonstration of tubercle bacilli in the sputum or gastric contents in 22 per cent of these patients, but the specific microorganisms were identified in the surgically removed tissue in all instances However, tubercle bacilli were cultured from only 7 per cent, 6 patients, of the surgically removed tissue. Less than a decade ago the concept of surgical exploration of the chest for ascertaining the nature of unexplained lesions was seldom advised, especially if the lesion was suspected of being tuberculous That morphologically identifiable tubercle bacilli are dead simply because they cannot be cultured is at the present time not a clinically acceptable thesis

Endobronchial Tuberculosis In apparently similar tissues the classification of endobronchial involvement varies appreciably with different pathologists In the 82 patients being considered, endobronchial involvement was present as determined by bronchoscopic examination in 3 patients, while in the examination of the surgical specimen, 12 patients were diagnosed as having involvement of the bronchi

Chemotherapy Only 1 patient did not receive chemotherapy, and as 79 of the 82 patients were operated on after 1948 the chemotherapy regimen was much the same, streptomycin, 1 to 2 grams every third day, and para-aminosalicylic acid, 12 grams daily Isoniazid, 300 mg daily, has now largely replaced para-aminosalicylic acid The duration of therapy has steadily increased, and in this group one-fourth of the patients who have been discharged from the hospital received seven to twelve months' chemotherapy, only 8 patients received more than one year of chemotherapy The amounts of streptomycin administered have decreased since the earlier period of 1947–1948, when massive doses of streptomycin were prescribed Only 3 patients have received more than 200 grams, and 43

per cent of the discharged patients received less than 100 grams which is a striking contrast to the 300 to 400 grams or more frequently employed in the patients treated by thoracoplasty Untoward manifestations of the drugs under present dosages and methods of administration are almost entirely eliminated Doubtless a very appreciable number of these patients could have successfully undergone the surgical procedures and their disease become inactive without chemotherapy The selection of such patients lacks much in exactness. However the utilization of chemotherapy in all patients causes few complications low mortality and morbidity and the excellent results leave little room for improvement They are probably not to be duplicated without chemotherapy The pre- and post-surgical chemotherapy periods are dependent on the nature and extent of the disease. More and more eight to twelve month periods of chemotherapy approximately equally divided between the pre- and post surgery period are being advised and followed Because of the uniformly excellent results, including no operative deaths no late deaths due to tuberculosis and all patients working able to work or their prognosis such as to anticipate that they will be able to work as soon as the recommended period of rest is completed lobectomy is preferable in the management of these patients

Thoracoplasty As a Space Closing Adjunct in Upper Lobectomy In only 3 of these patients on whom upper lobectomy was performed was thoracoplasty not accomplished This exhibits my belief that thoracoplasty is presently the best method of accomplishing a decrease in the size of the hemithorax which the remaining lung tissue after lobectomy is required to fill The use of air paraffin fat muscle and the now excellent plastic materials have not in my opinion replaced thoracoplasty A standard three-rib upper phase thoracoplasty is accomplished three weeks prior to a planned lobectomy The fourth and fifth ribs are removed at the time of lobectomy If the diagnosis is in doubt preoperatively the surgical exploration of the chest is commonly carried out first and if the removed lobe proves to be tuberculous an upper four rib thoracoplasty is carried out three weeks later the fifth rib having been removed at the time of lobectomy A thoracoplasty performed after lobectomy is of course less effective in preventing reexpansion of the remaining lower lobe

Crushing of the phrenic nerve within the hemithorax at the time of lower lobectomy decreases the size of the space which the upper lobe is required to fill. On this basis it is occasionally practiced but without a clear estimate as to its effectiveness being possible

Results The results have been unexcelled in our experience There were no operative deaths Two late deaths occurred neither being due to tuberculosis and the disease was inactive at the time of the patients death All others are well working able to work or their prognosis is excellent and complete rehabilitation is anticipated

Lobectomy for Tuberculoma The pulmonary tuberculoma frequently breaks down liberating viable tubercle bacilli and resulting in spread of the disease[17] It is this type of tuberculomatous lesion which is usually treated by lobectomy The well circumscribed subpleural firm nodule is surgically amenable to wedge excision Between these two ranges of opera

tive procedures the segmental resection of certain tuberculomatous lesions is feasible During 1947 to 1952 inclusive, 23 patients were treated by lobectomy for tuberculoma lesions, 18 of these had cavitary and 5 noncavitary disease Three have been classified as far advanced, 19 as moderately advanced, and 1 as having minimal tuberculous disease In only 2 of the cavitary lesions was roentgenographic evidence lacking The upper lobe was the site of involvement in 22 cases, and the lower lobe in 1

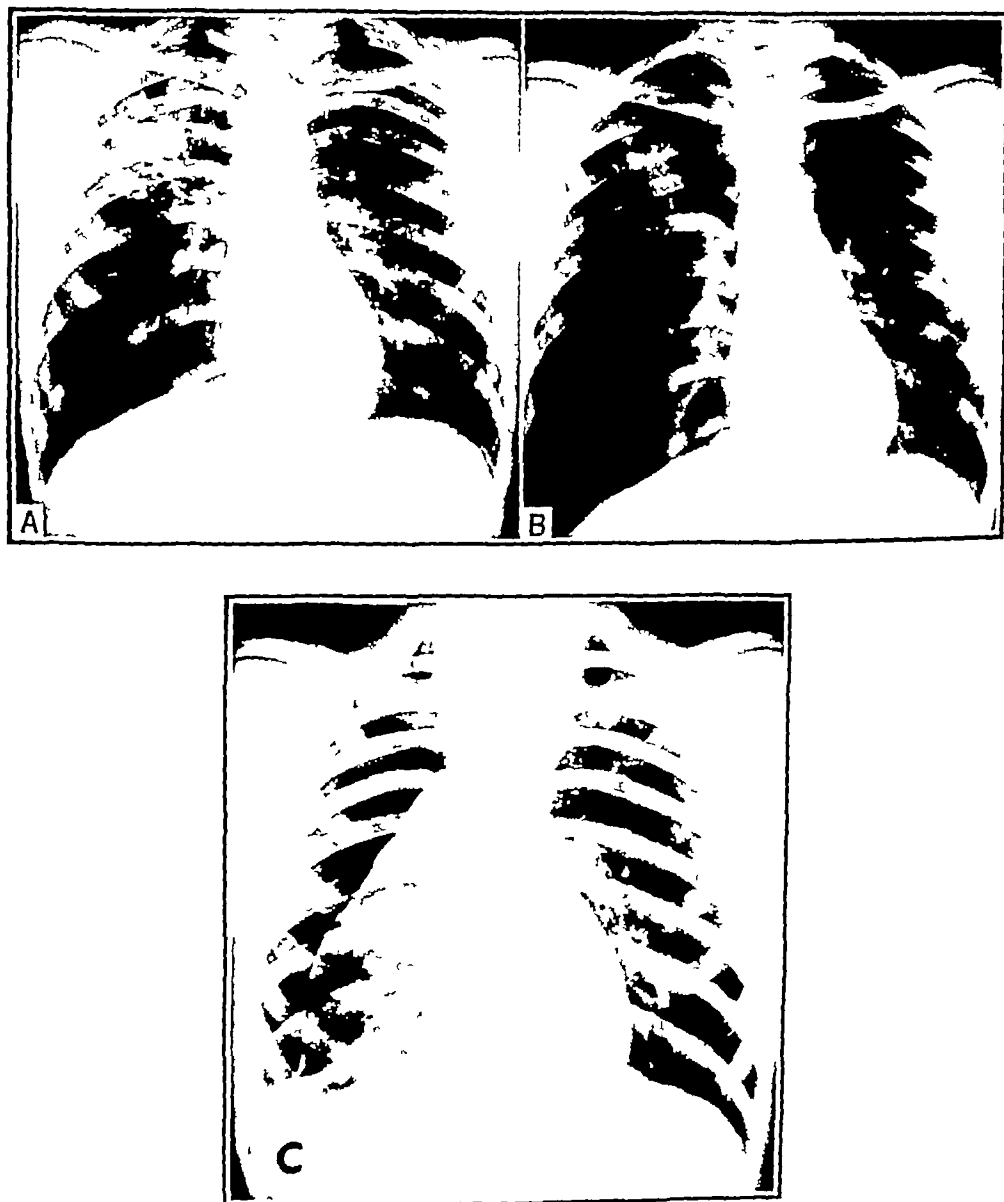


Fig. 50—Tuberculoma developing from a large cavitary lesion after collapse therapy, lobectomy performed Patient died two and one-half years later due to disease progression *A* February 18, 1946 Large cavity, right upper lobe *B* April 23, 1946 Ineffective artificial pneumothorax Closed intrapleural pneumonolysis accomplished in June, 1946 *C* August 20, 1948 Area of increased density in collapsed upper lobe, tuberculoma Lobectomy, right upper lobe, and five-rib thoracoplasty was performed during February and March 1949

instance Thoracoplasty with removal of either three or five ribs was accomplished in all patients having upper lobe cavitary disease The only major complication was the late development of a bronchopleural fistula in 1 patient who died of disease progression (Fig 50) Of the 23 patients 1 is dead and 1 is unable to work because of chronic brucellosis all others are well working or able to work.

Streptomycin was administered alone in 14 patients for a period of six months or less In the others para aminosalicylic acid was added to streptomycin Only 5 patients received chemotherapy for more than six



Fig 51 —Lobectomy for suspected but unproven tuberculoma *A* October 22 1949 Lesion right upper lobe *B* Right upper lobe November 7 1949 Tuberculoma suspected but not proven. Patient is well and has completed a three years course in the study of law after lobectomy (1) Apical segment. (2) Posterolateral segment (3) Anterolateral segment (4) Indurated area

months The dosage of streptomycin was 100 grams or less in 14 patients and exceeded 300 grams in 1 patient

The cavitary size based on measurements of the surgically removed lobe in the 18 patients demonstrating such lesions was as follows 1 cm 6 2 cm 4, and 3 cm 1 In 7 patients the measurements were not recorded The patients with cavitary lesions were hospitalized continuously for an average of 22 5 months 10 5 before and 12 months after surgery The known disease duration was six months or less in only 4 patients and in 10 the duration exceeded three years the longest being eleven years All of those with a duration of more than three years had cavitary lesions in the excised lobe

The age variation was considerable Two patients were twenty-one years of age or younger, 12 between the ages of twenty-two and thirty, six between thirty-one and forty, and 3 over forty Twenty-one were Caucasians, 1 Negro, and 1 Asian

Lobectomy for Suspected Tuberculosis Sixteen patients in our experience have had lobectomy for suspected but unproven tuberculosis This means that the sputum or gastric washings were repeatedly negative on examination for acid-fast bacilli and the specific organisms were not identified in the surgically removed specimen The histopathologic examination of the removed lobe and clinical manifestations were interpreted as of tuberculous etiology despite bacteriological negativity All of these patients are well and working The possibility of these lesions being due to fungous infection or some other ill-defined etiological agent is possible, but we have been unable to verify this conjecture (Fig 51)

Follow-up Data All patients have been followed in the group treated by lobectomy during the period 1947–1952 The 39 who have undergone lobectomy during the first six months of 1953 are still hospitalized

Complications The complications of lobectomy have been few Bronchopleural fistula developed in 2 7 per cent and empyema in 2.3 per cent All occurred in patients with cavitary disease Spread or reactivation of the disease in the same or opposite side during the first six months postoperative period occurred in only 1 9 per cent Four other patients demonstrated evidence of reactivation after a period of six to eighteen months Only 10 patients had major complications including bronchopleural fistula, empyema or spread In Table 31 are listed the complications of lobectomy including those which occurred following thoracoplasty performed on patients treated by lobectomy

Table 31. Complications of Lobectomy (Including Thoracoplasty) 261 Patients

Atelectasis, requiring bronchoscopy (3 followed thoracoplasty)	22 (8 4%)
Bleeding, requiring opening of the wound	2 (0 8%)
Embolism, pulmonary, followed thoracoplasty	1 (0 4%)
Empyema (All were cavitary disease)	6 (2 3%)
Fistula, bronchopleural (All were cavitary disease)	7 (2 7%)
Pleural fluid, requiring thoracentesis (6 followed thoracoplasty)	21 (8 %)
Spread or reactivation, within 6 months after lobectomy (All were cavitary disease)	5 (1 9%)

Results The results in our experience with lobectomy in the treatment of pulmonary tuberculosis have been gratifying They have been recorded above in the different categories as to indications and nature of disease, *i e*, cavitary, non-cavitary, tuberculoma lesions, and suspected but bacteriologically unproven case problems The over-all results in the 261 patients so treated indicate 90 per cent have had excellent results, meaning

that they are working, able to work, or that their prognosis is so favorable that it is seemingly assured that they will reach the goal of complete rehabilitation at an early date In the 139 patients having cavitary disease evidenced in the excised lobe 85 per cent are in the above category while 98.5 per cent of those who did not have demonstrable cavitation have or are reaching the above goal Only 26 patients did not obtain an excellent result. Seventeen are dead and in 3 deaths were not due to tuberculosis as this disease was inactive at the time of death Nine are alive and in each the sputum is positive

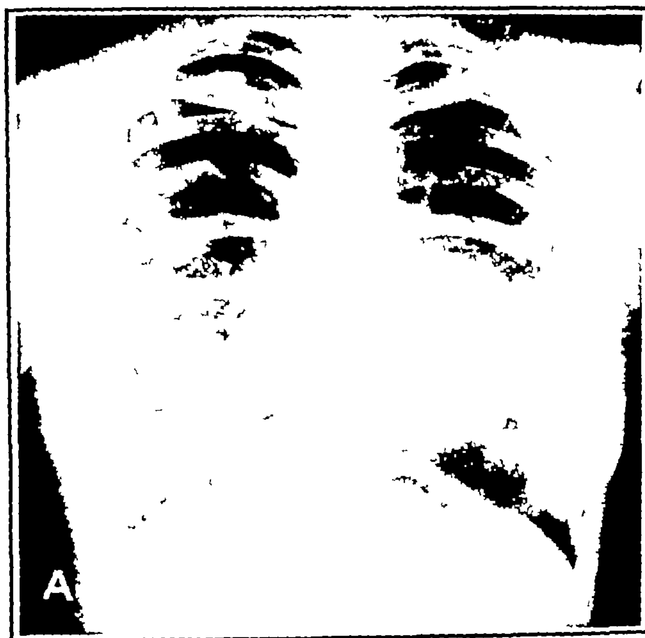
There were 4 operative or early deaths 1.5 per cent This includes all deaths from all causes within a period of sixty days after lobectomy Thirteen additional patients have died during the follow-up period of six months to five and one-half years

Summary Lobectomy has in our experience since the advent of chemotherapy been the most effective surgical method of treatment of far advanced or cavitary tuberculosis (Fig 52) The indications for its application are now clearly defined and have been discussed Early disease detection and effective chemotherapy have made earlier application of extirpative surgery feasible often permitting segmental resection or wedge excision. Lobectomy continues to be the choice procedure in approximately 40 per cent of the patients treated surgically at Fitzsimons Army Hospital

Appraisal of This Experience and Its Influence on the Surgical Therapy of Pulmonary Tuberculosis Since the advent of streptomycin it has been clearly demonstrated that lobectomy is a highly feasible and practical means of treating pulmonary tuberculosis It has been adaptable both from the standpoint of the extent of disease and surgically in approximately half of the patients undergoing major surgical efforts It has acted as a spearhead in the present wide use of extirpative surgery extending this field of therapy to encompass an ever increasing percentage of patients amenable to surgery in the treatment of pulmonary tuberculosis

Pneumonectomy *General* Pneumonectomy in the treatment of pulmonary tuberculosis has seldom been indicated in my experience Only 22 patients in a group of 547 treated by extirpative procedures during the period 1 January 1947 through 30 June 1953 have received pneumonectomy a percentage of only 4.2 In 6 instances it was performed following thoracoplasty failure and in only 17 patients 3 1 per cent was pneumonectomy selected as the procedure of choice

The principle of pneumonectomy is fundamentally different than any other extirpative procedure The removal of all lung tissue unilaterally leaves an empty hemithorax deprived of lung tissue to cover the severed bronchial stump and fill the hemithorax. These features are I believe far less favorable to bronchial stump healing than in lobectomy segmental or wedge excision. Pneumonectomy brings about a complete deprivation of the function of one lung a most significant difference from any other extirpative procedure. Further it is impossible to accurately assess the involvement of the contralateral lung tissue and despite a negative interpretation of serial chest roentgenograms the presence of tuberculous lesions in the opposite lung in patients requiring pneumonectomy is a



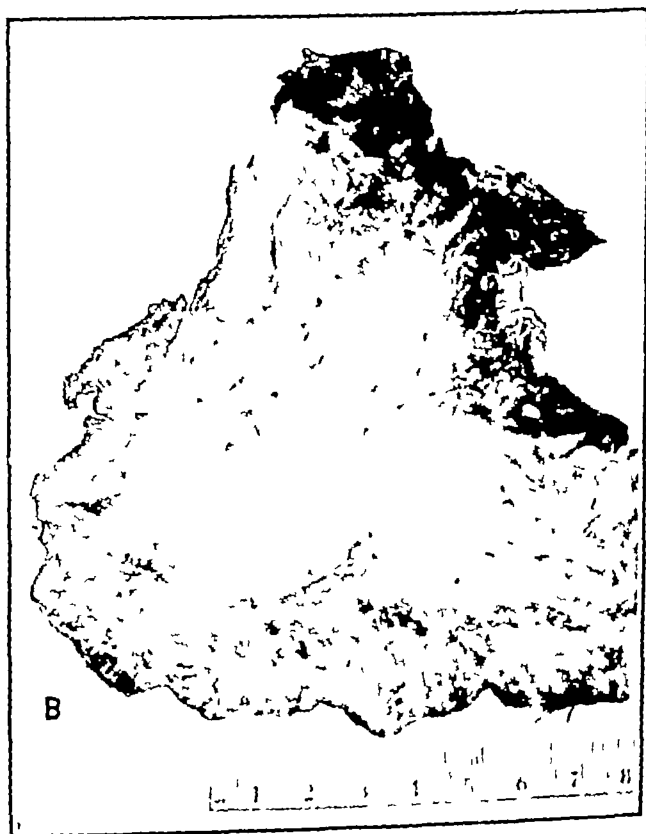


FIG 52 – Lobectomy for tuberculosis *A* March 1, 1951 Increased density left lower lobe Sputum positive *B* Surgical specimen, contracted left lower lobe containing extensive small cavitation was removed March 23, 1951 Streptomycin 160 grams Patient is well

reasonable assumption This is a basis upon which to expect that the incidence of reactivation or spread to the contralateral lung will be as high or higher than in other extirpative procedures Finally there is a large empty hemithorax which must become occupied or obliterated and there are differences of opinion as to the preferable method of meeting this problem I favor thoracoplasty [11,12] In our experience bronchopleural fistula and empyema as complications following pneumonectomy are more numerous than with any other extirpative measure Because of these fundamental differences we have seldom considered pneumonectomy indicated

Indications Pneumonectomy is advised if there is main stem bronchial tuberculous stenosis and total or almost total unilateral loss of lung function due to extensive unilateral tuberculous involvement Pneumonectomy occasionally is indicated in thoracoplasty failure to convert the sputum to negative if other sources for the positive sputum are not demonstrable In one patient injury to the main pulmonary artery necessitated a pneumonectomy rather than an upper lobectomy which was contemplated Suitable pulmonary function should be evidenced by the opposite lung and it should be considered roentgenographically and bacteriologically free of active disease.

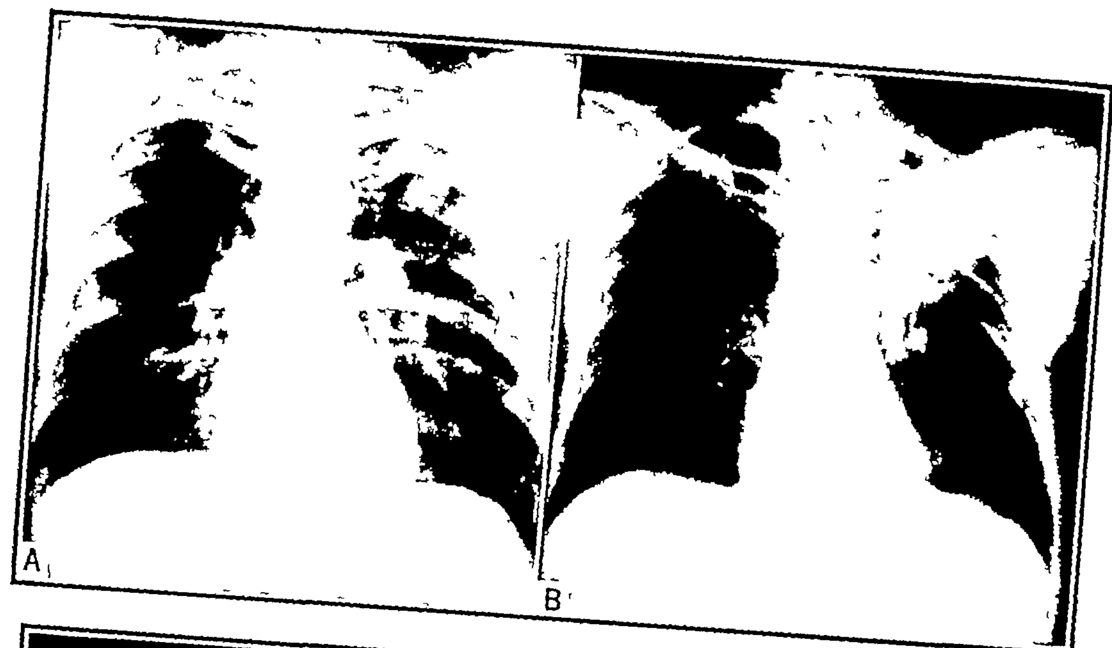
Age Race Sex and Lung Removed There was 1 eleven-year-old patient the only one in the group less than twenty two years of age Eleven were between twenty-two and thirty years of age while 5 were over forty years of age. There was only 1 over fifty years old Sixteen were males Five were Negroes 2 of whom are dead 1 was an Asian and the other 16 were Caucasians The right lung was removed in 5 patients and the left in 18 or 78 per cent Sixty nine per cent of the patients treated by lobectomy had the upper lobes removed and of these 68 per cent were the left upper lobe Only 1 patient treated by pneumonectomy did not have a thoracoplasty to decrease the size of the hemithorax

Extent of the Disease The tuberculous disease was considered far advanced in 20 of the 23 patients and moderately advanced in 3 patients

Cavitation Roentgenographic evidence of cavitation was considered present in the involved lung in all instances during the course of the disease In 7 of the 23 patients a cavity was not demonstrated in the surgically removed lung In 10 patients the cavity size varied from 1 to 3 cm in diameter in 4 this measurement was greater than 3 cm while in 2 patients the cavity size was not recorded

Duration of Disease Prior to Pneumonectomy Ten of the 22 patients had a known duration of more than thirty-one months prior to pneumonectomy while in only 3 was the duration six months or less

Chemotherapy Fourteen of the 22 patients had chemotherapy for six months or less and none had chemotherapy for more than eighteen months The dosage and amount of streptomycin varied greatly Eleven patients had less than 100 grams 6 had 101 to 200 grams 1 had 202 to 300 grams and 1 patient had over 400 grams Five are still receiving chemotherapy in the hospital Six received streptomycin alone and the others had streptomycin combined with para-aminosalicylic acid or other agents


A
B

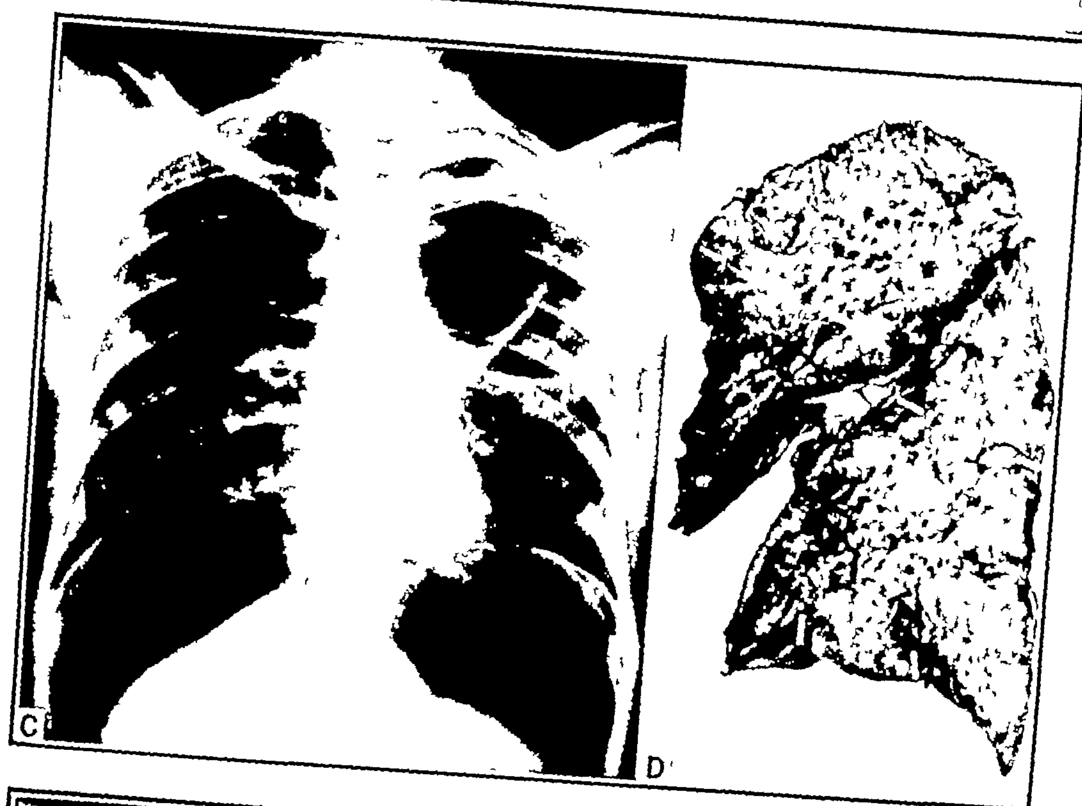

C
D





FIG 53 —Pneumonectomy for tuberculosis. *A* May 28 1951 Lesion, right upper lobe. Sputum negative for acid-fast bacilli. Patient's age, 57 No symptoms. Not hospitalized. *B* August 23 1952 Same patient as *A* increase in size of lesion. *Symptoms of weight loss of 65 pounds from January to July* 1952 Exploratory thoracotomy performed September 9 1952 Carcinoma was considered as the likely etiology as repeated sputum examinations, ex*cept for one culture were negative for acid-fast bacilli.* The lung contained considerable nodular involvement throughout the left lower lobe as well as extensive disease in the upper lobe. Pneumonectomy was elected as the *preferable method of surgical therapy* Tubercle bacilli were numerous in the excised lung There was marked bronchial stenosis of the upper lobe, and the caseopneumonic component predominated. Patient is still hospitalized. *C* Pneumonectomy for destroyed lung. Ten cm. cavity in left upper lobe and a 4 cm. cavity in the left lower lobe Extensive disease throughout lung Patient is well but not working *D* Surgical specimen, left lung Pneumonectomy for main stem bronchial stenosis. Disease duration of eight years. Massive dosage of chemotherapy had been administered. Throughout the removed lung there was extensive multiple cavitation averaging 2 cm in diameter and nodular disease Patient has been well and leading a normal life since two years after pneumonectomy *E* Pneumonectomy for thoracoplasty failure performed eight years previously Sputum converted after pneumonectomy *F* Pneumonectomy left for main stem bronchial involvement and destroyed lung Colonel H W Mahon Pathologist, Fitzsimmons Army Hospital, whose experience has been considerable, made the following note in his report 'This is the most extensive caseoulcerative tuberculous bronchitis I have seen in surgical specimens of lobes and lung Patient is well and leading a normal life. Pneumonectomy performed on April 24, 1950 *G* Tuberculous bronchiectasis and cavitary disease in a contracted lung. (Forsee *et al* courtesy of Ann. Int. Med.)

Other Surgery Surgical procedures which had been performed on the involved side prior to pneumonectomy in an effort to arrest the tuberculous disease included closed intrapleural pneumonolysis in 2 patients and phrenemphraxis in 6 Thoracoplasty had failed to close cavitation in 6 patients

Length of Hospitalization The total continuous hospital stay prior to and after pneumonectomy was less than six months in only 1 patient

while 12 were hospitalized more than nineteen months The preoperative stay was less than six months for 7 patients, and more than nineteen months in 5 patients, averaging thirteen months. The post-pneumonectomy stay averaged ten months, varying from less than six months in 8 patients to more than eighteen months in 3 patients Three patients died less than three weeks after operation These data further confirm the feasibility of the working rule of one year post-surgical hospitalization following lobectomy or pneumonectomy

Complications. Three patients, or 13 per cent, had a broncho-pleural fistula and empyema postoperatively. Three patients had a spread to the opposite lung. One patient developed an empyema but did not have a bronchopleural fistula

Endobronchial Tuberculosis All patients were bronchoscoped, and 8 patients had bronchoscopic evidence of tuberculosis sometime prior to pneumonectomy. Of special interest is the fact that 18, 82 per cent, had evidence of endobronchial involvement in the excised lung

Tubercle Bacilli in the Removed Lung Tissue The specific microorganism was identified in 16 of the removed lungs, only 1 specimen was negative, and in 5 patients the record of this study was not available Unfortunately, the records as to the growth of the microorganism on culture is not sufficiently complete to be of value in this group of patients All patients had positive sputum examinations for acid-fast bacilli prior to pneumonectomy (Fig. 53)

Results. Of the 23 patients treated by pneumonectomy, 5 are dead, 4 dying within sixty days or less following operation, an operative mortality of 17 per cent. Five patients are still hospitalized and in 4 the sputum is negative; 1 is hospitalized because of mental disease The prognosis in 3 for complete rehabilitation is considered excellent Twelve patients are well and 9 are actually working forty hours per week There is no follow-up on 1 patient.

Appraisal of This Experience in the Surgical Therapy of Pulmonary Tuberculosis This experience coupled with that regarding lobectomy and other extirpative measures confirms the very limited indications for pneumonectomy. It is emphasized that the case material considered in this book represents that most favorable to surgical therapy, yet an incidence of over 25 per cent of pneumonectomies in a large group of tuberculous patients treated surgically appears excessive

Segmental Resection. *General* The increasing use of segmental resection has been brought about as a result of the beneficial effects of chemotherapy in the resolution and localization of the tuberculous process in the lung. This should not be construed, in my opinion, to indicate that the operative procedure is in itself to be preferred to lobectomy Enthusiasm for its application should not result in enforcing its use in an over-zealous effort to conserve lung tissue which, though less involved than the segment or segments removed, contains appreciable tuberculous disease Lobectomy in such instances is preferable Some hesitancy should be exhibited in applying segmental resection for small residual foci, in that exploration of the chest in instances wherein roentgenographic evidence of such a lesion is doubtful seems ill-advised With the acceptance of these concepts,

segmental resection becomes a procedure which we are employing with increasing frequency. In fact during 1952 segmental resection was employed in 35 patients in comparison to 45 patients treated by lobectomy and during the first six months of 1953 there have been 30 patients treated by lobectomy and 50 treated by segmental resection. As pulmonary tuberculosis most often involves the apical and posterior portions of the upper lobe the apical and posterior segments were removed in 75 per cent of all segmental resections performed during 1947–1952. Because segmental resection has been employed much more frequently in 1952 and 1953 than previously a considerable proportion of the patients are still hospitalized. Segmental resection in contradistinction to wedge excision requires the isolation and division of the respective bronchus and vascular structures (see Fig 28). Sixty five patients have been treated by segmental resection during 1947–1952.

Duration of Disease Prior to Surgery. The known disease duration prior to surgery was six months or less in 12 patients, seven to twelve months in 31 patients, thirteen to eighteen months in 10, nineteen to thirty months in 4, and more than thirty-one months in 8 patients, thus indicating the wide range of applicability of segmental resection (Fig 54).

Length of Hospitalization. Twenty-one patients are still hospitalized. Of the remaining 44, approximately 90 per cent were hospitalized one year or less after segmental resection. Actually 14 were discharged within six months or less, 25 within seven to twelve months and 5 within thirteen to eighteen months which represents the longest period of post surgical hospitalization. The total period of hospitalization was less than six months in only 3 patients while 21 patients required nineteen to thirty months and only 2 remained a longer period. The over-all hospital stay closely approximates our experience with lobectomy. A significant factor is the increasing tendency toward protracted chemotherapy to obtain maximum disease localization prior to surgery. In any event the presentation to the patient of a reasonably definite statement as to the period of hospitalization which will be required is a major advance in the therapy of pulmonary tuberculosis and contributes immeasurably to the patient's acceptance of recommended therapy.

Extent and Nature of Disease. The patients treated by segmental resection were classified as far advanced in 6 instances, moderately advanced in 42, and 17 patients had minimal disease. Cavitation was present in the surgically excised tissue from 24 patients and in 41 there was no evidence of cavitation. Cavitary size as determined by measurements of the surgical specimen revealed cavitation of 2 cm or less in 12 patients and larger than 2 cm in 6 while the measurements were not recorded in 6 patients. The largest cavity measured 6 cm in diameter. In general segmental resection is often the preferable procedure for small cavitary and localized associated lesions. Disseminated lesions and cavitary disease are in general best treated by lobectomy. Of the 6 patients with far advanced disease treated by segmental resection all are well. Five of the 65 segmental resections were for tuberculomatous lesions.

Age, Race and Sex. These factors seem to have no appreciable influence on the results. Eight patients were twenty-one years of age or



A



Fig. 51 d resection 1 1951 Lesion right lower lobe Sputum
or tuberculous d as inactive January 31, 1953 Onset
nine month specimen removed on December 11,
lar segment lobe , Tuberculous cavity, *B*
bronchus

younger 31 were between twenty two and thirty years of age 24 between thirty-one and forty while only 2 were forty years of age Sixty-one were Caucasians and four were Negroes while 49 were males and 16 were females

Chemotherapy Chemotherapy in patients treated by segmental resection is receiving a close appraisal Certain data related to chemotherapy in this group of patients are depicted in Table 32

Table 32 Chemotherapy in Segmental Resection 65 Patients*

No Patients	*Duration of Chemotherapy*	*Dosage of Streptomycin*	*Result—Working Able to Work or Excellent Prognosis for Complete Rehabilitation*
31	6 Months or less	100 grams or less	22
		101–200 grams	7
11	7–12 Months	100 grams or less	1
		101–200 grams	10
1	13-18 Months	300–400 grams	1
TOTAL 43			41 (95 3%)

One patient did not have chemotherapy 21 are still hospitalized

Indications The question as to the need for surgical intervention is often appropriate as doubtless many of these patients would recover without it and not suffer later reactivation. On the other hand the ability to predict with accuracy whether or not any given patient with a lesion containing tubercle bacilli will experience progression or regression of the disease process is lacking The small lesions become the larger ones minimal disease is the forerunner of a far advanced process and surgical excision of the small diseased area is feasible and practical The surgeon who advocates this latter concept accepts a responsibility probably even greater than advocating surgical therapy in far advanced disease The surgeon is charged with the responsibility of all factors concerned with operation and the only death in this series resulted from administering incompatible blood by transfusion This is offered to reemphasize that blood transfusions are often not needed and are fraught with a degree of danger

Complications The postoperative complications in our experience with segmental resections in pulmonary tuberculosis have been more frequent than after lobectomy There have been few major complications but several which prolong morbidity and are disturbing to the patient Fifty patients had an entirely uneventful postoperative course Atelectasis requiring bronchoscopic aspiration of retained secretions was required in 4 patients Thoracentesis was required in 6 patients after the intercostal drainage tubes were removed Wound infection occurred in 1 patient An empyema arose in 1 patient and a bronchopleural fistula and empyema developed in another Their responses to therapy were excellent the fistula closed and the empyema cleared in three weeks Both patients are well and working

Results The long term results in this group of patients is not available due to the large percentage who have been operated upon during the past eighteen months However, certain encouraging information in this regard is available Of 30 patients operated prior to 1952, 28 are well, working, or able to work One died, an operative death due to incompatible blood transfusion, and 1 still has a positive sputum from contralateral lung disease During and since 1952, 85 patients have undergone segmental resection Of the 24 patients operated during 1947–1952 who had cavitary lesions, there have been no deaths, 9 of these have been recently operated upon and are still hospitalized, only 1 of these has a positive sputum Of the 15 other patients only one is not well, while all others are well, working, or able to work Of the 41 patients who did not have cavitary disease, 4 were not bacteriologically proven Twenty-eight are working or able to work, 1 is dead, and 12 have been recently operated upon and are still hospitalized In evaluating the results in relation to the extent of the disease, they are very satisfying (Table 33)

Table 33. Results of Segmental Resection. 65 Patients

No Pts	*Extent of Disease*		*Still Hospitalized Sputum Neg*	*Not Able to Work, Sputum Positive*	*Dead*	*Able to Work*
5	Cavitary	Far Adv	2	0		3
16	Cavitary	Mod Adv	4	2		10
3	Cavitary	Minimal	3	0		0
1	Non-cavitary	Far Adv	0	0		1
25	Non-cavitary	Mod Adv	11	0		11
11	Non-cavitary	Minimal	1	0		10
4	Suspected (Unproved bacteriologically)				1	3
65			21	2	1	41

Summary Sixty-two or 95 4 per cent have an excellent prognosis

Wedge Excision *General* The removal of tuberculous lung tissue by wedge excision of localized lesions has markedly increased as the selected method of surgical management since the advent of the chemotherapy era In our experience there have been approximately 8 times as many patients treated by this method in 1952 as compared to 1947 During the period January 1, 1947 through June 30, 1953, 109 patients have been treated by wedge excision and 95 of these were treated prior to 1953 The common factor in this development has been chemotherapy Streptomycin has been the basic drug employed, and increased understanding of its dosage, method of administration, and combination with other agents has resulted in a striking improvement in the resolution and localization of pulmonary tuberculous lesions Ninety-six per cent of patients treated by wedge excision during 1947-1952 are well, working, able to work, or their prognosis is so favorable as to anticipate full rehabilitation as soon as the recommended period of rest is completed

Indications Two basic considerations comprise the indications for wedge excision First localized lesions are usually situated peripherally and subpleurally These may represent the residual foci of previously larger areas of disease involvement or initially detected lesions which may have recently appeared or they may have been present and remained unchanged for months or years. Cavitation may or may not be present If present the cavitation is usually small It is thus evident that wedge excision is a surgical method applicable to a rather wide variation of the disease process and is confined technically to lesions which are localized near the periphery of the lung tissue If the corresponding bronchus and vascular structures require individual isolation and ligation segmental resection of the diseased area or lobectomy is selected Thirty patients treated by wedge excision had tuberculomas This lesion is fully discussed in Chapter 2 page 31 In 52 per cent of the tuberculoma lesions treated surgically during 1947–1952 the wedge excision procedure was employed

Extent of Disease None of the 95 patients treated by wedge excision during the period 1947–1952 was classified as far advanced They were about equally divided into the categories of moderately advanced or of minimal disease according to the National Tuberculosis Standards Bacteriological confirmation of tuberculosis is lacking in 18 of the 30 patients Prior to 1951 we did not employ a satisfactory staining technique for the demonstration of Histoplasma capsulatum and it is probable that in several of the unproven lesions these microorganisms may have been identified by the presently available periodic acid-Schiff stain [20]

Cavitation Cavitation was demonstrated in 22 of the surgical specimens The cavitary size was not recorded in 4 patients in 4 it was between 1 and 2 cm in diameter and in 14 it was 1 cm or less In 3 the tubercle bacilli were not identified in the surgical specimen but had been demonstrated preoperatively in the patient s sputum

Age Race and Sex The age variation in this group of patients varied from eighteen to fifty-seven Ten patients were twenty-one years of age or less while 5 were more than fifty years The largest age group comprised 44 patients in the twenty two to thirty year category Twenty-eight were between thirty-one and forty years and 8 between forty-one and forty nine years Seventy-seven were males and 18 females Eighty-six were Caucasians only 6 were Negroes and 3 were Asians

Chemotherapy The dosage duration and agents administered to patients who underwent wedge excision was not appreciably different than in those treated by other extirpative measures except in one respect This exception was the relatively large number 13 who did not have chemotherapy These were in the group of patients in whom bacteriological confirmation was lacking and generally represented lesions of known long duration without the patients displaying symptoms Streptomycin combined with some other drug usually para-aminosalicylic acid was administered to 69 patients while 13 received streptomycin alone

Twenty five patients are still in the hospital and have received or are receiving streptomycin combined with para-aminosalicylic acid or isoniazid Of the 70 patients who have been discharged 35 receive 100 grams

or less of streptomycin, 22 received between 101 and 200 grams, and 13 did not receive chemotherapy

Duration of Disease Prior to Wedge Excision Often the localized lesions suitable for wedge excision are of comparatively long duration prior to their removal They represent, on the part of the patient, lesions which produce no symptoms, minimal symptoms, or the lessening of symptoms due to the healing of more extensive lesions The latter group comprise the residual foci remaining after effective resolution brought about by chemotherapy and the rest regimen It is the area in which increasing use of segmental resection and wedge excision is applicable Seventy-five patients, or 78 5 per cent, had a known duration of disease of one year or less, indicating that an appreciable number of lesions in this group represented residual foci Forty-one per cent of the 95 patients had a known duration of six months or less, while in 20 patients the duration was more than a year and in 6 of these it was more than thirty-one months The results of surgical therapy were no better in those with a prolonged disease duration

Other Surgery The continuing decrease in the use of multiple therapeutic procedures is desirable In this group of 95 patients, 2 had had closed intrapleural pneumonolysis and 4 had had phrenemphraxis on the side of the wedge excision Four had received artificial pneumonthorax therapy for relatively short periods, less than one year on the operated side Thoracoplasty was not performed in 78 of the 95 patients In 17 it was accomplished, and in 14 patients it consisted of a three-rib upper phase thoracoplasty prior to the exploration of the lung On determining that the disease area was removable by wedge excision further stages of thoracoplasty were not performed The fourth rib is usually resected in order to explore the lung Three patients had a two-stage, five-rib thoracoplasty performed

Length of Hospitalization. The average length of continuous hospitalization before and after wedge excision was fifteen months In only 6 patients was this period less than six months and only 1 had a period longer than thirty months This latter patient is well and is now performing full military duty Twenty-five are still hospitalized The average stay in the hospital after surgery was nine months The period of hospitalization before surgery has decreased slightly in this group as compared to the patients treated by other extirpative measures Only 2 patients were hospitalized more than nineteen months before surgery and the average was six months The period of hospitalization referable to the asymptomatic tuberculoma lesion in the absence of a presurgical diagnosis is a significant consideration In the absence of demonstrable tubercle bacilli in the surgically excised tissue, *i e*, the mature tuberculoma, hospitalization is brief, approximately forty-five days If tubercle bacilli are demonstrated, the regimen for the management of active pulmonary tuberculosis is invoked

Complications There were no major complications such as empyema or bronchopleural fistula Pleural fluid was removed by thoracenteses in 8 patients after the intrapleural drainage tubes were removed. Two patients required bronchoscopic aspiration of secretions

Results Ninety-six per cent of the patients treated by wedge excision are well working able to work, or their prognosis is good and early return to work is seemingly assured Nineteen had cavitary lesions and all are in the above work category Forty five of the 40 patients in whom there was no cavitary lesion in the excised specimen have achieved excellent results as defined above The 27 patients who do not have bacteriologically proven tuberculosis are well Only 1 patient is dead an operative death The patient suffered cardiac arrest after return to the ward following a first stage thoracoplasty, three weeks after wedge excision had been performed None of the surviving patients has positive sputum Follow up data are lacking on 2 patients and the other surviving patient is not well although the sputum is negative

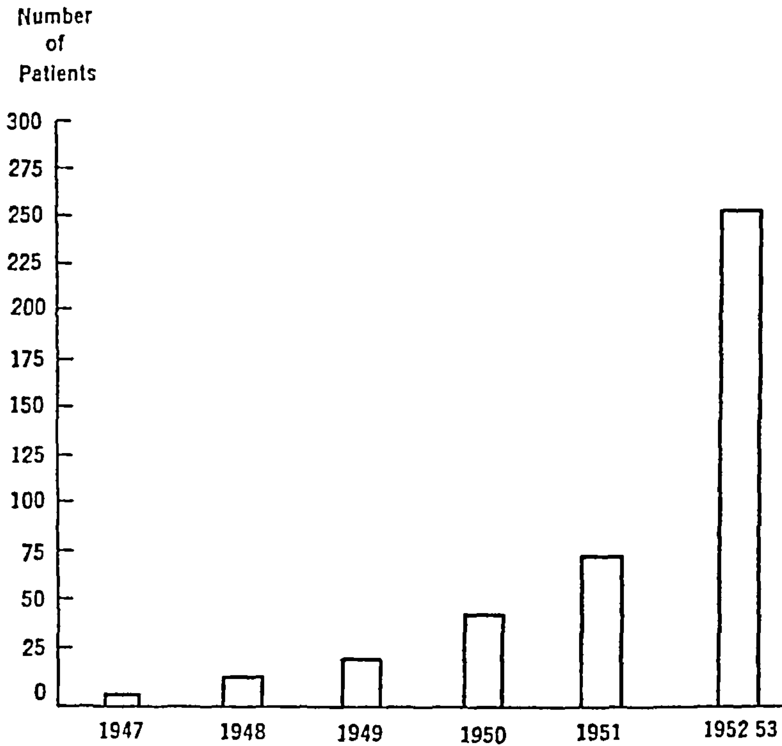
Extirpative Surgery for Localized Tuberculous Disease *General* The evolution which has characterized the surgery of pulmonary tuberculosis since the introduction of streptomycin presents interesting facets Recapitulation of these developments uncovers the recent past and enlightens the future The changes in the application of surgical procedures have resulted principally from the increasing beneficial effects of the chemotherapeutic agents rather than the superiority of a favored surgical technique The operative procedure must fit the patient and his disease rather than attempting to make these features fit the operation

Definition The localized lesions described herein are defined as any tuberculous process cavitary or non-cavitary involving an area not exceeding in extent that occupied by one lung above the level of the second costochondral junction at the time of extirpative surgery Initially and during the course of the disease the definition further limits the process to one lobe upper or lower This does not restrict the disease process to minimal as defined by the National Tuberculosis Association s Diagnostic Standards [21]

Case Material During the period January 1 1947 through December 31 1952 there were 200 patients in this category of localized lesions representing 60 per cent of the patients treated by extirpative surgery In 1953 the percentage of patients with localized lesions treated surgically as compared to the total subjected to extirpative methods may exceed the 77 per cent noted in 1952 (Graph VI) It is this trend of operating upon less extensive and more localized disease which is extending and so markedly improving the results of extirpative surgery When 90 per cent or more of the patients undergoing surgical treatment for pulmonary tuberculosis are in this category and this is in sight it is reasonable to predict that 98 per cent of those so treated will make a complete and lasting recovery

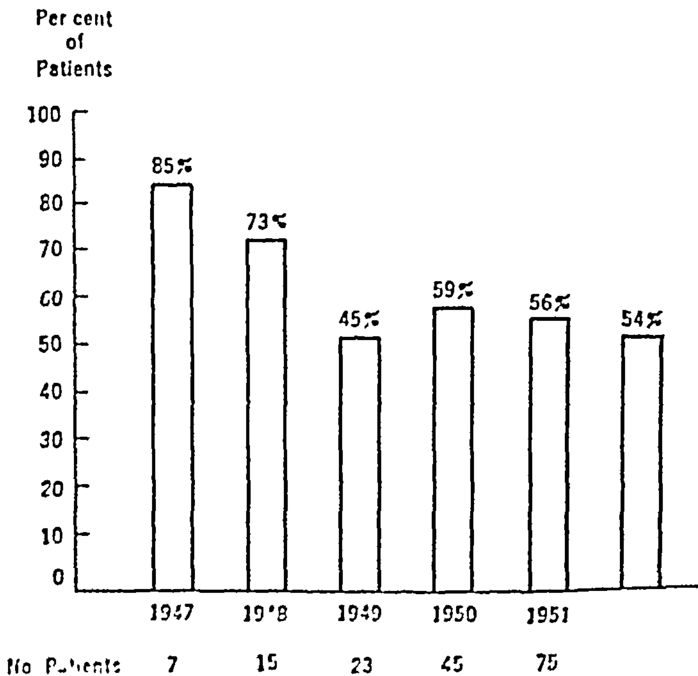
Classification The lesions encountered were principally classified roentgenographically as fibrocaseous or caseofibrous and these two types of lesions are classed together as fibrocaseonodose in the histopathologic examination of the surgically excised tissue in 96 per cent of the patients The significance of studying the pathology of pulmonary tuberculosis using tissues from the living patient has become widely appreciated due to the application of extirpative surgical methods Grouping the surgically removed lesions on the basis of histopathology as tuberculoma cavitary and caseonodose readily lends itself to the clinician s use By this group-

*Graph VI. Increasing Frequency of Patients With Localized Pulmonary Tuberculous Lesions Treated by Extirpative Surgery**



* Estimation on first six months of 1953

Graph VII. Routine Roentgenographic Examination of the Chest Leading to Detection of Pulmonary Tuberculosis (Localized Lesions Treated by Extirpative Surgery)



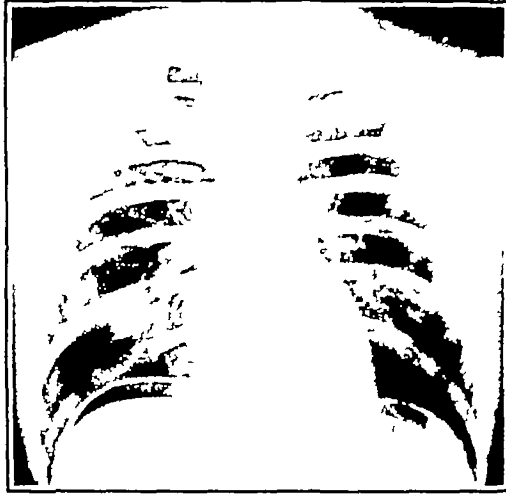
ing the lesions in the 266 patients are tuberculoma excluding 22 cavitary lesions 33 cavitary 101 including the cavitary tuberculomas caseonodose, 132

Detection by Routine X ray Examination of the Chest The use of mass chest surveys consisting of having large groups of the population undergo x ray examination of the chest is an excellent method of detecting evidence suggestive of tuberculosis as well as many other diseases manifested in the chest The repetition of such examinations at yearly intervals or at the onset of symptoms referable to the chest on all persons admitted to hospitals as a part of the employment examination of persons in industry business and similar situations warrants effective encouragement In the military service this plan of roentgenographic examination at frequent intervals such as induction annual physical examinations separation from the service reenlistment on admission to hospitals and enroute overseas provides an excellent facility for the early detection of pulmonary diseases (Graph VII)

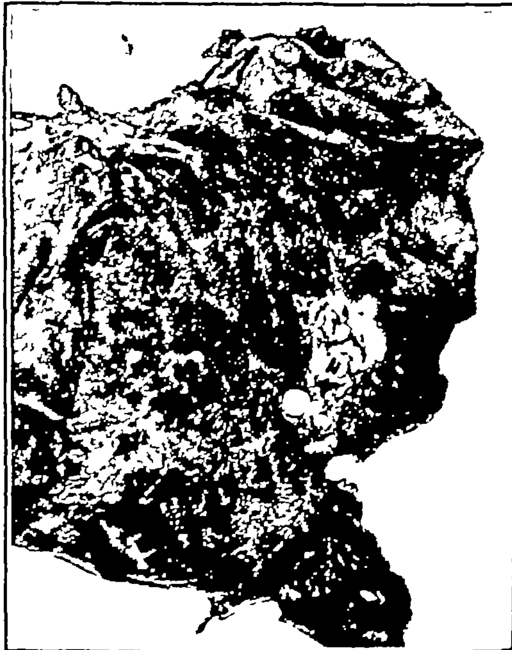
Duration of Disease Prior to Surgery Many more persons are being operated upon earlier as a result of the effectiveness of chemotherapy Percentage-wise the difference has probably been less striking and this is doubtless due to the increasing number of persons with protracted disease who are now readily accepting surgical therapy In 1948 4 or 27 per cent had a disease duration of more than five years and in 1952 the percentage was 17 The more significant factor is the earlier application of surgery *e g* 60 per cent of the patients undergoing surgery for localized lesions in 1952 were known to have had active pulmonary tuberculosis for less than one year prior to therapy and in approximately one-half of these the period was six months or less. Early detection affords the best opportunity for effective therapy and by way of reflection this is so vastly preferable to the years required by and the uncertain result of chasing the cure prior to the present era that comparison is odious (Fig 55)

Cavitation The presence of cavitation is always of serious importance Thirty-eight per cent of the patients grouped in this category of localized lesions had evidence of cavitary lesions in the surgically excised tissue (Graph VIII) The detection of cavitation prior to operative removal is dependent principally upon roentgenographic findings which though satisfactory contain an error of approximately 25 per cent in not detecting cavities which in the removed tissue are 2 cm or less in diameter The clinician should be expert in the interpretation of chest roentgenograms and in fluoroscopic examination This applies equally to the phthisiologist and the surgeon The added information readily available to them, including the patient s clinical course temperature sputum production weight fluctuation etc aids in evaluating roentgenographic findings In the localized lesions containing cavities approximately 90 per cent were 2 cm or less in diameter as measured in the removed tissue. The increasing tendency to perform surgery on less and less extensive disease coupled with improved localization of the lesion due to chemotherapy is markedly increasing the use of segmental resection of cavitary lesions. The decreasing incidence of cavitation in the surgically removed lobes accompanies the greater use of lobectomy in those patients whose nodular lesions,

though principally confined to one lobe, are dispersed and have not coalesced or become destructive (Graph IX) The low rate of spread of the disease associated with 261 consecutive lobectomized patients, 2 per cent, is further supporting evidence of the efficacy of chemotherapy



A

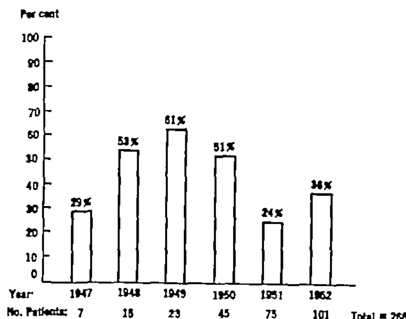


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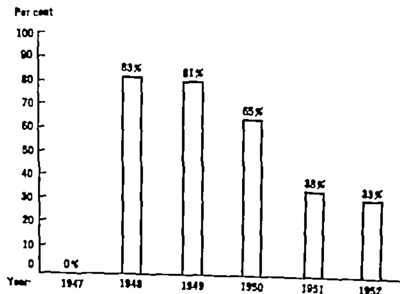
FIG 55 —Localized tuberculous lesions, 1952 *A* February 2, 1952 Soldier, age 26, ill five months Small cavitary lesion, left upper lobe Lesion unchanged after four months of chemotherapy Sputum negative since operation Patient discharged February 10, 1953 He is well *B* Surgical specimen Small amount of nodular lesions and residual cavitation The lingual division was large, uninvolved, and was not removed

Tubercle Bacilli Demonstrated Prior to Surgery A decade ago a patient rarely underwent surgery for pulmonary tuberculosis when the tubercle bacillus had not been isolated from the sputum or gastric contents. This situation no longer prevails, and in approximately 40 per cent of these 266 patients repeated efforts had failed to demonstrate the specific organisms in the sputum or gastric culture prior to surgery. Also worthy of thought is the fact that in 24 per cent the final diagnosis was based on evidence that the tubercle bacillus was noted in the sputum or gastric

Graph VIII Cavitation in the Surgically Removed Lung Tissue of Localized Lesions



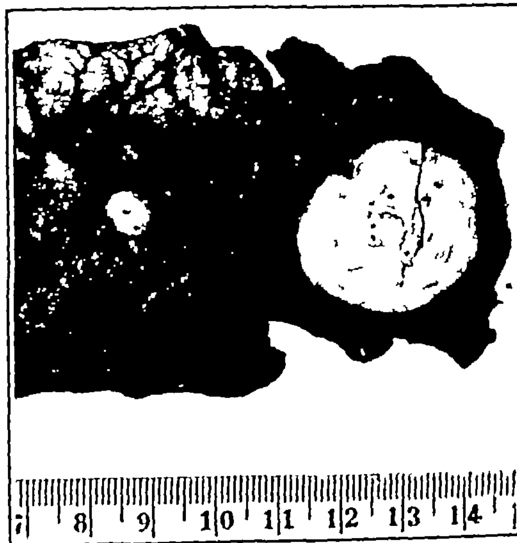
Graph IX. Cavitation in Removed Lobes from Patients with Localized Lesions



content, although not demonstrated in the surgical specimen The histopathology was interpreted in this light as tuberculosis The specific organism was demonstrated in the sputum, gastric contents, or the surgically excised tissue in 86 per cent of the 266 patients In the remaining patients the diagnosis is based solely on the clinician's evaluation of the patient's clinical course, and the histopathological examination of the surgically excised tissue by a pathologist experienced in diseases of the chest These criteria are, of course, subject to error, and future developments may



A



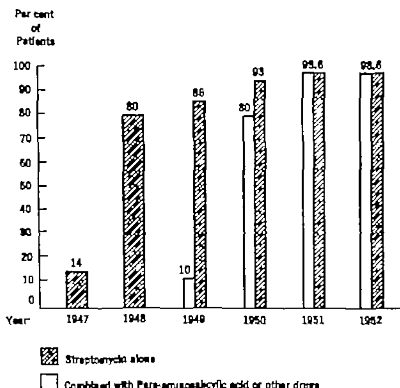
B

FIG 56 —Histoplasmoma *A* Round dense lesion left lower lung field Proved to be histoplasmoma *B* Surgical specimen Histoplasma capsulatum identified in the lesion

lessen mistakes. Recently the use of the periodic acid-Schiff stain in identifying Histoplasma capsulatum in the surgically excised so-called round pulmonary lesions has shown that many of these lesions are due to Histoplasmosis. These were formerly classified as of tuberculosis etiology but the tubercle bacilli could not be demonstrated in the specimen (Fig 56).[28]

Increased Use for Surgery. The widening of the scope of surgical therapy in pulmonary tuberculosis is evidenced by the fact that approximately 1 of every 4 patients at Fitzsimons Army Hospital who has pulmonary tuberculosis is now receiving surgical therapy. It is reasonable to anticipate that with the very low mortality, morbidity and splendid

Graph X. Chemotherapy for Localized Tuberculous Lesions

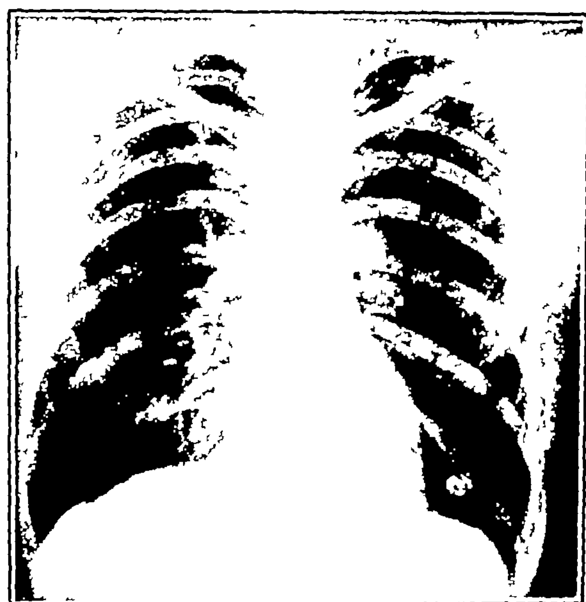


results a further and probably greatly increased percentage will be treated by surgical measures. In the pre-chemotherapy era when thoracoplasty was the "sheet anchor" of surgical therapy less than 5 per cent of the tuberculous patients at Fitzsimons were treated by major surgical efforts.

Chemotherapy. The increasing use of extirpative surgical methods during the past few years has been predicated almost entirely upon the development and improved methods of administration of the chemotherapeutic agents. The story of the surgical extirpation of localized lesions is the story of chemotherapy in pulmonary tuberculosis. The period prior to 1950 may be characterized as the time required to adjust to these new "wonder drugs." Their dosages, regimens and the response of the human

host were not clearly understood During 1949 para-aminosalicylic acid was introduced, and when combined with streptomycin markedly decreased the development of bacterial resistance to streptomycin therapy This permitted much longer use of the latter, employing smaller total dosages and administration at three-day intervals rather than daily The essence of such a regimen is the more prolonged and effective use of the drugs, six to eighteen months, which permits maximum resolution and localization of the disease and protection against infection of the pleura when tuberculous lung tissue is transected at operation

Other beneficial drugs have been developed and employed Isoniazid is effective when given alone, but it is preferable to use it as a part of the streptomycin regimen, and it has largely replaced para-aminosalicylic acid because it is much more palatable and equally effective The preferable regimen is streptomycin 1 or 2 grams every third day, depending on the individual's weight, and 300 mg of isoniazid daily Patients weighing 150 pounds or less are given 1 gram of streptomycin Only 1 per cent of the patients treated by extirpative surgery in 1952 did not receive streptomycin In all instances it was combined with para-aminosalicylic acid or other drugs, and there has been a marked lengthening of the period during which chemotherapy is being administered (Graph X)



A



B

FIG 57 —Localized tuberculous lesion (tuberculoma) left, 1948 *A* Round lesion, left lower lobe *B* Cross section of surgical specimen, tuberculoma

Another significant factor in the increasing use of extirpative surgery in pulmonary tuberculosis is emphasized by the rapid decline in the incidence of the tuberculoma lesions In 1947 and 1948 this type of lesion occurred in 80 per cent of the patients with localized lesions who were treated surgically In 1952 only 1 per cent of the lesions were classified as tuberculoma (Figs 57, 58 and 59)

Choice of Surgical Procedure in Localized Lesions The factors of prolonged use of streptomycin without the development of resistance to

the drug improved resolution and localization of remaining lesions together with improved surgical techniques have enhanced the use of segmental resection In 1952–1953 wedge excision and segmental resection of tuberculous lesions in localized lesions composed approximately three-fourths of the surgical procedures employed and from which remarkably good results were obtained

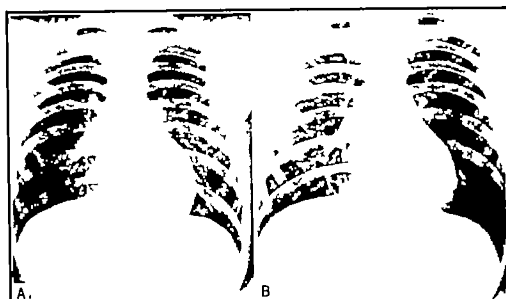




FIG 58.—Localized tuberculous lesion 1951 *A* July 26 1951 Large cavity right lower lobe. *B* April 4 1952 Decrease in size of cavitation. *C* Surgical specimen. Segmental resection basal segments, right lower lobe. Nodular lesions and 1 cm cavity present. A 23-year-old white soldier became ill in July 1951 Sputum positive for tubercle bacilli Eight months chemotherapy and bed rest resulted in considerable decrease in size of cavity Segmental resection, basal segments, right lower lobe, and crushing of right phrenic nerve performed May 2 1952. In March 1953 the patient was discharged from the hospital and placed on temporary military retirement. It is anticipated that he will return to military duty in 12 to 18 month

Complications The complications have been few There were no spreads of the disease associated with surgery Two patients evidenced reactivation or spread one year after surgery Two patients developed bronchopleural fistulae and empyema, 0 75 per cent, one following a segmental resection, the other after lobectomy One wound infection occurred and 1 patient clinically had a pulmonary embolism from which he recovered Few patients, 10, developed pleural fluid requiring thoracentesis, 4 in wedge excision, 4 in segmental, and 2 in the lobectomy group The meticulous operative surgery and splendid postoperative care is largely responsible for the low incidence of complications

Results The results of extirpative surgery in the treatment of localized lesions have been almost phenomenal One hundred sixty-five of the patients in this group were operated prior to 1952 Of the 160 surviving patients on whom there are follow-up data, 98 7 per cent are well, working, or able to work (Graph XI)

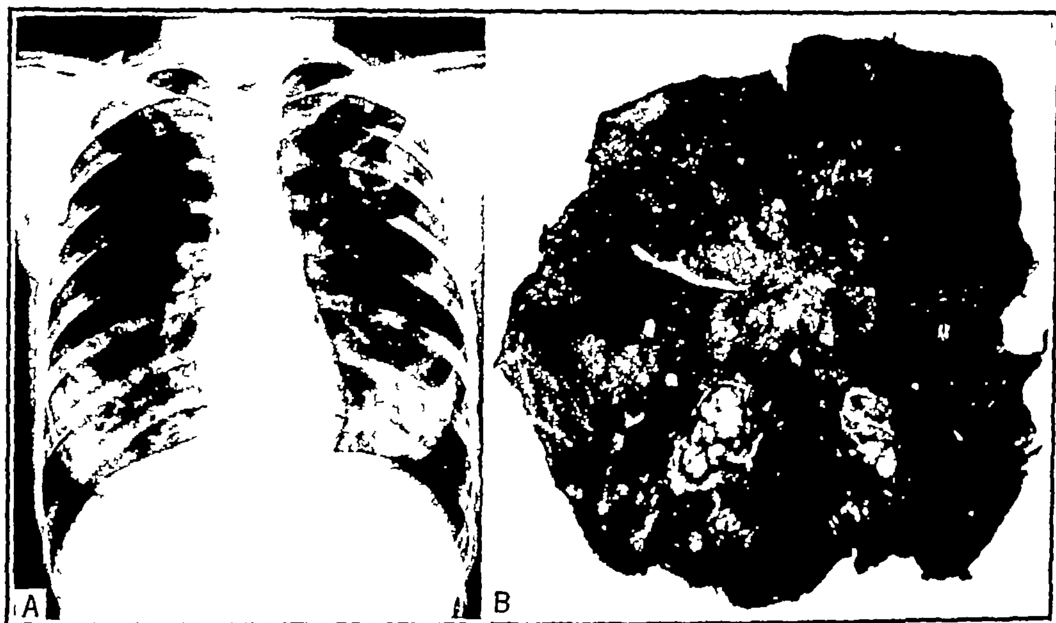


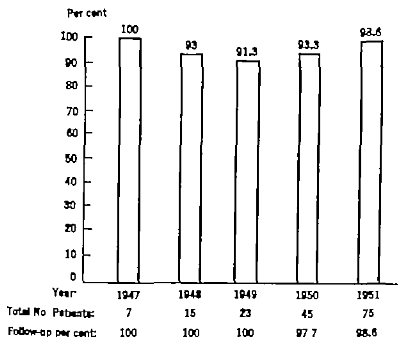
FIG 59 —*Localized tuberculous lesion, 1951* *A* Large cavity, left upper lobe, decreased markedly in size under chemotherapy and artificial pneumothorax *B* Surgical specimen, segmental resection, apico-posterior segments, left upper lobe Area of cavitation reduced to firm nodule noted in specimen This is a rather extreme type of localized lesion now being treated by chemotherapy and extirpative surgery Patient is well Sputum negative since operation

Decortication. *General* Decortication of the lung in the treatment of pulmonary tuberculosis is included here as the most appropriate place for its presentation In this disease decortication is a very different problem than its application in the management of traumatic hemothorax In the former the underlying lung parenchyma is chronically diseased in contradistinction to the latter in which a normal lung has suffered trauma. The "peeling" from the pleural surfaces of the abnormal layer of fibrin and

fibrous tissue, which has formed as a result of a traumatic hemothorax is usually accomplished with ease and the cleavage plane readily developed The adherence of the fibrous peel to the pleural and parenchymal tuberculous disease increases the difficulty in developing the cleavage plane and the separation of the peel from the lung may be impossible The best results, therefore are obtained in instances wherein the disease in the lung is minimal or moderate in extent [18]

Indications The unexpanded lung resulting from artificial pneumothorax therapy or pleural effusion is the preferable indication In instances wherein an empyema has developed decortication may be indicated The objective of decortication is to obtain reexpansion of the lung to fill the

Graph XI Results * Working or Able to Work. Localized Tuberculous Lesions Two Years or More After Surgery 165 Patients



* Three patients are dead only one had active tuberculosis at the time of death. there are no follow-up data on two patients, and two patients have positive sputum

hemithorax. Ventilation is improved but oxygen uptake by the lung is often slow to improve Removal of diseased parenchymal tissue may be combined with decortication of the remainder of the lung If the etiology and extent of parenchymal disease is not ascertainable prior to decortication which is often the situation it is usually preferable to carry out decortication and evaluate the feasibility of further surgery after reexpansion of the lung If the sputum or gastric washings have been repeatedly and recently within three months positive for acid-fast bacilli an upper first stage thoracoplasty should precede decortication and both procedures deferred until after adequate chemotherapy If lobectomy is contemplated an upper first stage thoracoplasty should precede decortication and

extirpation of the lobe The second stage thoracoplasty, removal of the fourth and fifth ribs, is accomplished at the time of decortication It is not unusual to encounter the need for decortication in instances wherein extirpative surgery is being performed, although the lung filled the hemithorax prior to surgery A portion of the lung may be markedly shrunken and following the release of its encasement by decortication, will expand, carry on improved function, and fill the space formerly occupied by the removed lobe This type of case problem is not included in this discussion

The indications employed in our series of 55 patients treated by decortication alone or in association with other surgical procedures were (1) unexpanded lung following artificial pneumothorax therapy, 20, (2) pleural effusion, 29 Sixteen had acid-fast bacilli demonstrated in the pleural fluid prior to decortication, and (3) empyema due to mixed infection, 6

Decortication was accomplished at the same time as extirpative surgery in 18 patients as follows lobectomy, 15, segmental resection, 1, and wedge excision, 2

Pathogenesis The pathogenesis of the pleural peel is essentially the same whether it is due to an unexpanded lung following artificial pneumothorax therapy, effusion, or empyema In the latter, the peel develops quicker and to a greater degree The pathologic changes may vary considerably The earliest is that of opacity of the pleura which is richly vascularized and infiltrated with leucocytes and histocytes As the membrane becomes thicker the middle layer is more fibrous and the peripheral area contains more of the blood vessels The fluid in the space between the parietal and visceral attachments may be clear or turbid and contain acid-fast bacilli If an empyema is present the peel is usually densely adherent to the visceral pleura and underlying parenchymal disease The contents of the sac are purulent from which tubercle bacilli are often demonstrable The ever thickening membrane or peel may produce an infolding of the lung which does not, however, bring about fibrosis but rather the fibrosis is a product of the underlying parenchymal disease Determination of the degree of reexpansion which will occur following decortication cannot be based solely on a study of the pre-collapse roentgenograms, in instances of artificial pneumothorax therapy or pleural effusion, as extension of the disease may proceed in the compressed lung This does not lessen the importance of studying and evaluating the parenchymal disease by serial roentgenograms taken prior to compression of the lung

Technique The technical principles of decortication have been described by Weinberg [25] We favor removal of the visceral and parietal peel in toto, when possible The thick parietal peel prevents maximum chest wall collapse if thoracoplasty is employed and it also limits excursion of the thorax The cleavage plane between the lung and peel is somewhat easier established anteriorly as the parenchymal disease is usually greatest posteriorly. The peel is generally thinner anteriorly because of less underlying disease Small air leaks in the lung are seldom effectively sutured and the early reexpansion of the lung is more dependent upon continuous suction applied through 2 or 3 large catheters, 45 F, which emerge from the intrapleural space anteriorly and posteriorly The whole blood replace-

ment should exceed by about 50 per cent that estimated as lost by the dry weighed sponge method

Experience with Decortication Those patients in whom decortication is carried out because of the inability of the lung to reexpand after artificial pneumothorax therapy has brought about inactivation of the parenchymal disease which was minimal or moderate in extent, furnish the most suitable case material If the status of the underlying lung is not discernable preoperatively or if tuberculous etiology is not established two courses of action are available at the time of operation First decortication is accomplished the lung allowed to reexpand and evaluation of the parenchymal disease is made later Second if extirpative surgery is deemed advisable and accomplished, the remainder of the lung is decorticated If serial roentgenograms and other clinical data permit an evaluation of the extent of the original disease and its response to therapy much valuable information is gained If such an appraisal indicates tuberculosis far advanced cavitary or non-cavitary I believe decortication should seldom be selected as the principal surgical therapy Rather appropriate and adequate chemotherapy should precede extirpative surgery as the choice surgical method and a first stage upper phase extrapleural thoracoplasty accomplished prior to a lobectomy or pneumonectomy The lung tissue which remains should be decorticated if feasible Extensive parenchymal tuberculous disease in our experience has seldom been favorably influenced by decortication as the primary surgical therapy If pleural effusion is the principal indication for decortication the same general principles as outlined above are followed In the presence of a mixed infection empyema we seldom elect to carry out extirpative surgery (see Fig 16 p 44) The extent of the parenchymal disease prior to compression of the lung the duration of such compression and whether or not an empyema has developed are of paramount importance Necrotic foci and cavitary lesions may be reactivated by decortication The treatment of empyema by decortication does not lessen the need for observing other principles previously discussed

Results An evaluation of results relative to decortication is complicated when it is combined with other procedures In our experience 26 of the 55 patients have also received extirpative surgery or thoracoplasty Of the 18 who had extirpative surgery including 15 treated by lobectomy as well as decortication 2 patients are dead due to progression of the disease and 1 is still hospitalized and has a negative sputum Of the other 15 patients 9 are working full or part time and it is reasonable to predict that the others will be able to resume work as soon as their post-surgery period of rest therapy is completed Of the 8 patients who also received thoracoplasty 2 are dead Death was due to tuberculosis in 1 while in the other the tuberculous disease was inactive The other 6 patients have a good prognosis or are well There were 29 patients who had decortication alone There have been no deaths in this group and there is no follow-up on 2 patients. Of the remaining 27 1 continues to have a positive sputum 2 are sputum negative but it is anticipated that they will not be able to return to a work status. Of the other 24 a good prognosis is predicted or the patients are considered well

The evaluation of pulmonary function was accomplished in 7 of the 55 patients In all instances the ventilatory capacity was improved The evaluation of the oxygen uptake usually requires a long time for evaluation and is dependent, to a large degree, upon the extent of parenchymal disease A one-year post-surgical evaluation of pulmonary function has revealed, in several instances, appreciable improvement in oxygen uptake Preferably, pulmonary function studies should be accomplished prior to and at six-month intervals for two years following decortication [26]

Summary of Experience with Extirpative Surgery in the Treatment of Pulmonary Tuberculosis The surgical therapy of pulmonary tuberculosis of the past fifty years, spans a dismal and discouraging era to a period of brilliant achievement The first half of this period produced extrapleural thoracoplasty which required another decade to perfect The results achieved by thoracoplasty varied considerably and were not traceable directly to the surgical method but rather to the extensiveness of the disease process Operations on the phrenic nerve producing paralysis of the corresponding half of the diaphragm were also developed and applied during this period The second half of the century witnessed the development of closed and open intrapleural pneumonolysis and extrapleural plombage The further stabilization of the indications of these various procedures and their perfection was rewarding in increasingly better results Extirpative surgical efforts prior to about 1946 were considered interesting and stimulating but the concepts of surgery in pulmonary tuberculosis were rather serene and sterile for a decade before the advent of chemotherapy A long term evaluation was made of 511 patients treated by extrapleural thoracoplasty at Fitzsimons Army Hospital during the period 1926 through 1946 which demonstrated that only 10 per cent were well and working, three to twenty years after thoracoplasty Approximately 50 per cent were dead The results of thoracoplasty since about 1935 have been universally much improved over the preceding twenty-year period

With the advent of streptomycin and the continued development of other effective antituberculous drugs, the entire therapy and surgical considerations have been so altered that extirpative surgery is now the preferable therapy in more than 90 per cent of patients treated surgically. In addition, these developments have already brought about a five-fold increase in the percentage of patients who are treated by surgery The proper timing of surgery in the therapy of pulmonary tuberculosis and the definition of indications are now well understood and extirpative surgery is feasible on an even larger basis with increasingly good results In our experience with extirpative surgery in 443 patients during 1947–1952, all but 1 were adults, 91 per cent have achieved excellent results An additional 12 patients, or 2 7 per cent, have converted their sputum to negative but are unable to work

The recent trends toward the use of surgery earlier in the course of the disease as a result of the excellent aid in the resolution and localization of the disease process afforded by chemotherapy has permitted the application of surgery to more and more patients with less and less tuberculous disease The surgical removal of localized disease, cavitary or non-cavitary, is presenting such promising results that it seems reasonable to predict that more than 95 per cent of patients who develop pulmonary tuberculosis

and who do not suffer miliary or meningeal dissemination or empyema may through chemotherapy proper bed rest and surgery be completely rehabilitated

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Chapter

8

Results of Surgery in the Treatment of Pulmonary Tuberculosis

THE results of surgery in the treatment of pulmonary tuberculosis during the past seven years are vastly improved over that of the era prior to chemotherapy The long term evaluation, five to ten years, of disease inactivation following surgery must await an appropriate time interval All evidence now available indicates that these results will be equally striking in their excellency The following tables depict the results which have been obtained at Fitzsimons Army Hospital since the beginning of 1947 Included under the condensed tabulation designation that the patient is well are those whose prognosis is so favorable as to indicate complete rehabilitation The favorable features of early disease detection, good general condition of the patients, facilities for complete therapeutic management and rehabilitation have been constantly available and utilized The continuing improvement of these features will further erase the hazards of pulmonary tuberculosis

Table 34. Results of Extrapleural Thoracoplasty in the Treatment of Pulmonary Tuberculosis. 1947-1952. 313 Patients

No of patients who are well of tuberculosis		232
Working or able to work	212	
Hospitalized, sputum negative, prognosis good	11	
Hospitalized for other causes, tuberculosis inactive	2	
Tuberculosis, inactive Unable to work because of other unrelated diseases	7	
No of patients not well		39
Hospitalized and have positive sputum	16	
Not hospitalized, sputum positive	15	
Sputum negative but patient unable to work	8	
No of patients on whom follow-up data were not obtained		3
No of patients who are dead		39
Tuberculosis was the cause of death (Eight deaths within 60 days of operation)	31	
Deaths due to other causes, tuberculosis inactive	8	
Excellent results in 74 per cent		
Total No of patients		313

Table 35 **Results of Extrapleural. Thoracoplasty in the Treatment of Pulmonary Tuberculosis in Relation to Disease Duration 1947 1952 313 Patients**

Known Duration of Disease (months)	*No of Patients*	*Patients Well of Tuberculosis*	*Patients Not Well of Tuberculosis and No Follow-up*		*Dead*	
6 or less	52	46	3		3	
7–12	71	57	7		7	
13–18	48	36	6		6	
19–30	43	28	9		6	
31–59	37	22	8		7	
60 or more	62	43	9		10	
TOTALS	313	232 = 74%	42	+	39	(81 = 26%)

* No follow-up on 3 patients (1 0%)

Table 36 **Results of Extrapleural Thoracoplasty in the Treatment of Pulmonary Tuberculosis in Relation to Age of Patients 1947 1952 313 Patients**

Age in Years	*No of Patients*	*Patients Well of Tuberculosis*	*Patients Not Well of Tuberculosis and No Follow-up*		*Dead*	
21 or less	56	45	6		5	
22–30	137	108	18		11	
31–40	61	43	9		9	
41–40	36	25	5		6	
50 or more	23	11	4		8	
TOTALS	313	232 = 74%	42	+	39	(81 = 26%)

No follow-up on 3 patients (1 0%)

Table 37. Results of Extrapleural Thoracoplasty in the Treatment of Pulmonary Tuberculosis in Relation to Cavitary Disease 1947-1952. 313 Patients

	No of Patients	*Patients Well of Tuberculosis*	*Patients Not Well of Tuberculosis**		*Dead*	
	Cavitation Present					
	271	197 = 72%	38	+	36	(74 = 28%)
	Cavitation Not Present					
	42	35 = 83%	4		3	(7 = 17%)
TOTALS	313	232 = 74%	42	+	39	(81 = 26%)

* No follow-up on 3 patients (1 0%)

Table 38. Results of Extrapleural Thoracoplasty in the Treatment of Pulmonary Tuberculosis in Relation to Classification of Disease 1947-1952 247 Patients (39 Miscellaneous Not Included)

Type of Disease	*No of Patients*	*Patients Well of Tuberculosis*	*Patients Not Well of Tuberculosis and No Follow-up**		*Dead*	
Caseopneumonic	35	28	4		3	
Fibrocaseous	70	56	7		7	
Caseofibrous	72	59	10		3	
Fibrous	29	24	2		3	
Empyema	30	19	3		8	
Giant Cavitation	38	21	11		6	
TOTALS	274	207 = 76%	37	+	30	(67 = 24%)

* No follow-up on 1 patient (0 4%)

Table 39. Results of Extirpative Surgery in the Treatment of Pulmonary Tuberculosis 1947-1952. 443 Patients

Surgery	*No of Patients*	*No Patients Well of Tuberculosis*	*No Patients Not Well of Tuberculosis or No Follow-up**		*Dead*	
Lobectomy	261	235	9		17	
Pneumonectomy	22	14	3		5	
Segmental Resection	65	62	2		1	
Wedge Excision	95	91	3		1	
TOTALS	443	402 = 91%	17	+	24	(41 = 9%)

* No follow-up on 3 patients (0 7%)

Table 40 Results in Extirpative Surgery in the Treatment of Pulmonary Tuberculosis in Relation to Duration of Disease 1947 1952 443 Patients

Known Duration of Disease (mos.)	*No. of Patients*	*Surgery*	*Patients Well of Tuberculosis*	*Patients Not Well of Tuberculosis or No Follow-up*		*Dead*	
6 Mos. or less	57	Lobectomy	53	2		2	
	3	Pneumonectomy	1	1		1	
	12	Segmental Res.	12	0		0	
	39	Wedge Excision	38	1		0	
TOTAL	111		104 – 94%	4	+	3	(7 – 6%)
7–12	109	Lobectomy	100	4		5	
	1	Pneumonectomy	1	0		0	
	31	Segmental Res.	30	0		1	
	36	Wedge Excision	34	1		1	
TOTAL	177		165 – 93%	5	+	7	(12 – 7%)
13–18	26	Lobectomy	21	2		3	
	2	Pneumonectomy	2	0		0	
	10	Segmental Res.	9	1		0	
	8	Wedge Excision	8	0		0	
TOTAL	46		40 – 87%	3	+	3	(6 – 13%)
19–30	11	Lobectomy	10	0		1	
	6	Pneumonectomy	4	1		1	
	4	Segmental Res.	4	0		0	
	6	Wedge Excision	6	0		0	
TOTAL	27		24 – 89%	1	+	2	(3 – 11%)
31–59	31	Lobectomy	27	0		4	
	6	Pneumonectomy	3	1		2	
	3	Segmental Res.	2	1		0	
	5	Wedge Excision	5	0		0	
TOTAL	45		37 – 82%	2	+	6	(8 – 18%)
60 or more	27	Lobectomy	24	1		2	
	4	Pneumonectomy	3	0		1	
	5	Segmental Res.	5	0		0	
	1	Wedge Excision	0	1		0	
TOTAL	37		32 – 86%	2	+	3	(5 – 14%)
GRAND TOTAL	443		402 – 91%	17	+	24	(41 – 9%)

Table 41. Results of Extirpative Surgery in the Treatment of Pulmonary Tuberculosis in Relation to Age of Patient. 1947-1952. 443 Patients

Age in Years	*No of Patients*	*No Patients Well of Tuberculosis*	*No Patients Not Well of Tuberculosis or No Follow-up**		*Dead*	
21 or less	59	53	2		4	
22–30	197	184	6		7	
31–40	136	124	7		5	
41–49	42	35	1		6	
50 or more	9	6	1		2	
TOTALS	443	402 = 91%	17	+	24	(41 = 9%)

* No follow-up on 3 patients (0 7%)

Table 42. Results of Extirpative Surgery in the Treatment of Pulmonary Tuberculosis in Relation to Cavitary Disease. 1947-1952. 433 Patients

Surgery	*No of Patients*	*No Patients Well of Tuberculosis*	*No Patients Not Well of Tuberculosis and No Follow-up**		*Dead*	
		Cavitation Present				
Lobectomy	166	142	9		15	
Pneumonectomy	16	9	3		4	
Segmental Resection	24	22	2		0	
Wedge Excision	22	22	0		0	
	228	195 = 86%	14	+	19	(33 = 14%)
		Cavitation Not Present				
Lobectomy	95	93	0		2	
Pneumonectomy	6	5			1	
Segmental Resection	41	40	0		1	
Wedge Excision	73	69	3		1	
	215	207 = 96%	3	+	5	(8 = 4%)
TOTALS	443	402 = 91%	17	+	24	(41 = 9%)

* No follow-up on 3 patients (0 7%)

Table 43 Results in Lobectomy for Pulmonary Tuberculosis in Relation to Duration of Chemotherapy. 1947-1952 233 Patients*

Duration of Chemotherapy in Months	*No of Patients*	*No Patients Well of Tuberculosis*	*No Patients Not Well of Tuberculosis*		*Dead*	
6 or less	161	146	3		12	
7–12	64	56	3		5	
13–18	7	6	1		0	
19 or more	1	0	1		0	
TOTALS	233	208 = 82%	8	+	17	(25 = 11%)

* 25 patients are still hospitalized
3 patients did not have chemotherapy

Table 44 Results in Lobectomy for Pulmonary Tuberculosis in Relation to Age of Patient 1947 1952 261 Patients

Age in Years	No of Patients	No Patients Well of Tuberculosis	No Patients Not Well of Tuberculosis		Dead	
21 or less	40	36	1		3	
22–30	111	104	3		4	
31–40	79	72	4		3	
41–49	28	22	1		5	
50 or more	3	1	0		2	
TOTALS	261	235 = 90%	9	+	17	(26 = 10%)

Table 45 Results in Lobectomy for Pulmonary Tuberculosis in Relation to Duration of Disease 1947 1952 261 Patients

Disease Duration Months	No of Patients	No Patients Well of Tuberculosis	No Patients Not Well of Tuberculosis		Dead	
6 or less	57	53	2		2	
7–12	109	100	4		5	
13–18	26	21	2		3	
19–30	11	10	0		1	
31–50	31	27	0		4	
60 or more	27	24	1		2	
TOTALS	261	235 = 90%	9	+	17	(26 = 10%)

Table 46 Follow-up Data on Patients Treated by Extirpative Surgery or Extrapleural Thoracoplasty in Treatment of Pulmonary Tuberculosis. 1947 1952. 756 Patients

Surgery	No of Patients	Year of Last Follow-up 1950–51	1952–53	Dead	Hospitalized	No Follow-up
Lobectomy	261	4	220	17	20	0
Pneumonectomy	22	0	13	5	3	1
Segmental Resection	65	0	50	1	14	0
Wedge Resection	95	1	75	1	16	2
Thoracoplasty	313	3	254	39	14	3
TOTALS	756	8 (1 1%)	612 (80 9%)	63 (8 3%)	67 (8 9%)	6 (8%)

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